COMPARISON OF CERTAIN TEST RESULTS OF INDIVIDUALS
DEMONSTRATING A TYPE I BEKESY PATTERN IN THE
PRESENCE OF A SENSORI-NEURAL
HEARING IMPAIRMENT

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CHAPTER I

INTRODUCTION

Diagnostic audiometry proposes to determine a site of lesion within the parameters of the auditory mechanism relative to results from a battery of audiometric tests. Lesions in the outer or middle ear, the cochlea, the eighth nerve, the brain stem, and the auditory cortex are represented by significantly distinct response patterns to a diversified series of tests (20, 23, 24).

Indication of the cochlea as a site of lesion has proved to be most reliable when determined in conjunction with the following types of test results:

(1) There is no gap or difference between air conduction and bone conduction thresholds obtained by routine clinical audiometry (18, 33).

(2) Generally, at least moderately reduced word discrimination is in evidence (12, 13, 23, 48).

(3) The individual tested is able to detect smaller changes in sound intensity than the individual with normal hearing levels or with lesions in other parts of the auditory system (23, 25, 33, 37, 46).

(4) The individual with a "pure" cochlear lesion has no outer or middle ear pathology present as determined by an otologist (23, 26).

(5) The individual's threshold for continuous tone stimuli is generally higher than the threshold for interrupted tone stimuli: that is, tone decay or adaptation effect is present for a sustained stimulus (5, 17, 20, 22, 23, 29, 35, 36, 38, 39, 43, 49).

There are two major tests employed to evaluate response behavior to interrupted tone presentation as compared with prolonged, continuous tone presentation: the Tone Decay Test and automatic Bekesy audiometry. Because the results obtained from both tests are generally interchangeable (22, 23, 36, 38), only Bekesy audiometry will be discussed.

For diagnostic purposes, interrupted and continuous pure tone signals are utilized in Bekesy type audiometry. The relationship between the thresholds obtained with the two forms of tonal presentation is used for identifying a site of lesion (36, 38).

Individuals with normal hearing or conductive hearing losses characteristically produce essentially equivalent threshold levels for both types of tonal stimuli (22, 35, 36), while individuals with cochlear lesions generally have a higher threshold for the continuous stimuli above 1000 Hertz (Hz). Jerger (22, 23) classifies the results into Type I and Type II Bekesy patterns respectively.

A relatively small, but nonetheless important, percentage of individuals with cochlear involvement do not present a threshold shift or tone decay shift as determined with

Bekesy audiometry (23, 25). However, additional test responses are consistent with cochlear dysfunction. An investigation of individuals with sensori-neural impairment presenting a Type I Bekesy pattern, or one in which there is no significant difference or shift between threshold levels for sustained and interrupted stimuli, has not been reported.

The individual producing a Type I Bekesy pattern but manifesting responses indicative of cochlear lesion on additional diagnostic tests might exhibit some measureable auditory behavior that would differentiate his responses from the individual with sensori-neural impairment and a Type II Bekesy. A testing procedure which provides analysis of several independent types of response would appear most beneficial in examining the auditory behavior of these individuals with apparent cochlear involvement who do not exhibit a significant degree of threshold shift during presentation of a continuous, sustained tone.

In 1962 Katz (27) proposed the use of staggered spondaic words in assessing the synthesis ability of the central nervous system. The test can be administered in about twenty minutes and consists of forty spondaic words. One spondee of Katz' test, The Staggered Spondaic Word Test (SSW), is presented to each ear in a partially overlapping manner. In this procedure the second syllable of the first word and first syllable of the second word are presented simultaneously to different ears. At the conclusion of each test item or each group of two spondaic words, the subject repeats the items that he hears. Responses are recorded as correct or as errors of omission, distortion, or substitution of any of the four syllables in a test item. The errors are then totaled according to the number of mistakes for each ear condition, for the total ear condition, and for the total binaural percentage of correct response. A corrected spondaic word score is obtained to determine the percentage of error attributable to lesions below the auditory centers of the brain. The total percentage correct response score for each specified ear condition and for each total ear score is subtracted from the word discrimination score. Results can be analyzed in at least sixteen different categories (27) and yield valuable quantitative information about an individual's hearing loss.

Normative data concerning the SSW test, devised by Katz (26, 27, 28), indicates that individuals with peripheral or cochlear dysfunction have a reduced percentage correct score that is highly correlated with reduced word discrimination scores. Typically, reduced SSW scores are bilaterally depressed for individuals with cochlear lesion if the hearing loss levels are relatively symmetrical bilaterally.

Statement of Purpose

The purpose of this study is to determine if significant audiometric characteristics exist in individuals having cochlear lesions who trace a Bekesy pattern characteristic of individuals with normal hearing or conductive losses.

Investigation of Problem

The study was designed to investigate the following questions:

(1) Does the Staggered Spondaic Word Test of sequential patterning reveal differential information about an individual having a sensori-neural hearing disorder as established by a battery of audiometric tests but tracing a Type I Bekesy pattern?

(2) Do individuals tracing a Type I Bekesy pattern who otherwise present evidence of cochlear involvement perform differently on the Staggered Spondaic Word Test from those individuals exhibiting a Type II pattern in the presence of a sensori-neural impairment?

Definition of Terms

Articulation Function Curve: A graphic representation of the changes in intelligibility or correct recognition of words as related to the sensation level at which words are presented (2).

Auditory Fatigue: A temporary shift in auditory acuity following exposure to another auditory stimulus (49).

Central Hearing Disorders: A dysfunction of the cerebral cortex and subcortical areas down to the level of the midbrain (8).

Cochlear Lesion or Sensori-neural Hearing Impairment: An impairment of hearing due to damage of the inner ear (33).

Conductive Hearing Loss: An impairment of hearing due to damage or obstruction of the ear canal, drum membrane, or the ossicular chain in the middle ear (18).

Loudness Recruitment: An abnormal sensitivity to change in loudness versus intensity relation in cases of hearing impairment of cochlear origin (32).

Sensation Level: The pressure level of a sound in decibels (dB) above the threshold of audibility for the individual observer (18).

Speech Reception Threshold: The threshold intensity at which the individual can respond correctly to fifty per cent of the speech stimuli presented to him (34).

Spondaic Words: A combination of two monosyllabic words which are given equal stress.

Word Discrimination Score: The greatest percentage of monosyllabic word items a person can repeat correctly when speech is presented at a comfortable loudness level in a matrix of language (18, 33).

Review of the Literature

Automatic Audiometry

Automatic self-recording audiometry was introduced by Bekesy in 1947 (3). The principle of automatic audiometry for determining an individual's sensitivity threshold for hearing involves the subject's manipulation of the intensity of a tone by depressing a hand signal lever when the tone is just audible and releasing the hand signal lever when the tone is no longer audible. The action of depressing or releasing the lever reverses a motor which, in turn, decreases or increases the intensity of the tone stimulus. When the lever is depressed and then released in alternating fashion, the recording pen connected to the motor controlling the intensity will record the individual's threshold limits on an audiogram form moving slowly under the pen.

With the Grason-Stadler Bekesy Audiometer Model E-800-4 the threshold tracings may be obtained for the continuum of frequencies from 100 to 10000 Hz or may be obtained for any discrete or single frequency between 100 and 10000 Hz. This audiometer allows for two types of tone presentations. The interrupted or pulsed tone is a series of short beats, while the continuous tone is a steady or non-interrupted tone presentation.

The most widely used table or motor speed on the Grason-Stadler Model E-800-4 has a frequency change of one octave per minute with an attenuation rate of 2.5 dB per second (22, 29, 43). Presentation rate for the pulsed or interrupted tone is 2.5 dB per second. The threshold for a given frequency is usually interpreted as the mid-line point between the upper and lower limits of the tracing peaks for the interrupted tone tracing at a given frequency (22, 29, 42).

Since the introduction of Bekesy audiometry, numerous clinical applications and theories regarding its value have emerged. The major audiological manifestations investigated to date include auditory threshold sensitivity, loudness recruitment, tinnitus, auditory fatigue, and the determination of a site of lesion.

As a means of determining auditory threshold sensitivity, Bekesy audiometry has gained widespread acceptance. Bekesy (3) and Reger (44) advocate its use in place of conventional pure tone audiometry on the basis that the presented tone is always close to the subject's threshold and that time is not spent approaching threshold by decreasing or increasing the intensity of the tone manually. Jerger (23) indicates that Bekesy audiometry may eventually replace conventional pure tone testing.

The presence of heightened vertical peaks at variable intervals, particularly in the higher frequencies, was once thought to be indicative of the presence of tinnitus (3, 44). Later research has noted the presence of higher peaked tracings, but has not supported the contention that Bekesy audiometry can be used as an indirect test to determine the presence of tinnitus.

Some investigators have equated a reduced intensity range of a tracing excursion with the results of a loudness recruitment test (3, 41, 44). Reger states that it gives "an indication of the intensity difference limen at or near threshold which inherently demonstrates the presence or absence of recruitment at threshold in the pathological ear" (44, p. 1333).

Subsequent clinical investigation has not supported the assumption that the narrowed width of a tracing is directly indicative of loudness recruitment (22, 23). Jerger (23, p. 139) states that the narrowed amplitude width is "simply a phenomenon that may or may not happen when the disorder is in the cochlea."

As a clinical tool, Bekesy audiometry has shown to be of value in determining the effect of "fatigue" during an extended stimulus presentation and in determining the speed of recovery of hearing sensitivity after extensive exposure to loud noise (36, 39, 49).

For diagnostic purposes, both the interrupted and continuous tone presentations are utilized. The interrupted or pulsed tone is presented first. The thresholds obtained with the interrupted tone are essentially the same as those measured by manual audiometry (22, 23).

The continuous tone is then presented. Individuals having cochlear dysfunction generally exhibit increased threshold levels as a result of the sustained stimulation. Hood (19) attributes this increase to pathological adaptation or relapse. He defines adaptation as "the attainment of a state of equilibrium between the energy which is expended in the response and the energy which becomes available to maintain it" (19, p. 514). The prolonged stimulation, then, may cause a rapid decrease in response until the energy supply is restored to a level that is capable of stabilizing the sensation of the tonal stimulus. In Bekesy audiometry, the intensity level of the continuous tone is increased until the auditory receptors are able to respond to the sensation of a tone for an extended duration of time.

Individuals with normal hearing and conductive losses characteristically do not evince pathological adaptation during presentation of the continuous stimulus. If the cochlea is the site of lesion, a slight increase in intensity of about 10 to 20 dB may be necessary before the individual can achieve a stable response to the stimulus tone. Extreme adaptation levels may be observed in individuals with retrocochlear dysfunction. The sustained tone threshold may be as much as 30 to 50 dB greater than the threshold for interrupted tone signals for this group of individuals.

The response characteristics of individuals with cochlear and retrocochlear disorders may also be considered as functions of frequency and hearing loss levels. Subjects with sensori-neural involvement generally report similar thresholds for interrupted tones and continuous tones in the frequencies below 1000 Hz or when hearing loss levels are less than 35 dB (22, 31, 35, 36). At frequencies above 1000 Hz, the continuous tone threshold may differ as much as 25 dB from that of the interrupted tone (22, 23, 36, 38). If a sharp increase in threshold is evident in the lower frequencies, retrocochlear involvement may be suspected (22, 23, 36, 38).

The major classifications of Bekesy patterns frequently recognized in clinical audiometry at the present time are those proposed by Jerger (22, 23). In an investigation of tracings produced by 434 subjects utilizing both the interrupted and continuous stimulus Jerger identified four main tracing categories. He reported that Type I Bekesy audiograms are characterized by an interweaving or superimposed tracing for the two methods of tone presentations and are typically representative of individuals with normal hearing or conductive losses.

The Type II Bekesy shows an interweaving of the continuous and interrupted tracings in the lower frequencies up to about 1000 Hz. The continuous tone tracings then shift 10 to 20 dB below the interrupted tone tracking. It rarely shifts more than 25 dB below the threshold level of the interrupted tone. Individuals with cochlear involvement typically produce a Type II pattern, although a small percentage present a Type I pattern. Jerger (22) and Owens (35) both report that about one-fourth of the subjects with cochlear lesions, primarily those of undetermined etiology, show a Type I pattern.

Type III tracings are represented by a sudden shift of the intensity of the continuous tone, often 40 to 50 dB below interrupted stimulus tracing. Usually, the continuous tracing shifts to the intensity limits of the audiometer. The shift is not limited to any frequency range and often begins in the lower frequencies. Individuals with eighth nerve dysfunction typically produce the Type III tracing.

In Type IV Bekesy audiograms, the continuous tracing is decidedly lower than the interrupted tracing, but the drop is not as great or as sudden as that found in Type III tracings. There is generally no interweaving in the low frequencies between the two types of tracings. Individuals with eighth nerve disorders present either the Type IV pattern or the Type III pattern.

Despite the widespread clinical use of Jerger's categorizations of the types of Bekesy tracings, recent reports have suggested that the investigator be cautious when classifying a particular pattern in auditory diagnosis (21, 42, 43, 45). Robertson (45) emphasizes that the statements concerning the type of Bekesy tracing should be limited to an indication of a site of lesion rather than a definite cause suggested by the type of tracing. He reinforces Jerger's statement that "we cannot be sure that the absence of a particular pattern necessarily precludes the possibility of a disorder at a given site" (45, p. 368).

Price _et al_. (43) tested 129 subjects under thirty-five years of age with hearing levels of 0 dB or better. A fixed frequency Bekesy at one or two frequencies was administered utilizing both the interrupted and the continuous stimulus. The results showed that approximately forty per cent of the individuals tested traced patterns indicative of functional or organic disorders when interpreted with the categories proposed by Jerger. Two possible explanations were offered: "1. There is a considerable range of normal responses. 2. Many persons whose hearing appears to be normal by pure tone and speech may have a sub-clinical pathologic condition" (43, p. 142). To further clarify these observations, they stated that differences between the levels of the interrupted and continuous tone were a result of auditory adaptation. The authors indicated that if adaptation is, in part, a neural response then a certain degree of adaptation would be considered normal. However, the point at which adaptation enters an abnormal range has not been established.

In answer to the findings by Price, Jerger (21) replied with the following observations. The investigation headed by Price based classification results on the use of fixed frequency or discrete frequency tracings. Jerger maintained that his classifications were based on sweep frequency tracings and that the sweep frequency tracing proved more valid clinical data than the fixed tracing provided. Jerger supported the observation of Price's investigation that it was necessary to be cautious when interpreting the Bekesy tracings in predicting a site of lesion.

Owens (35) investigated the cochlear and retrocochlear tracing categories as reported by Jerger. His subjects consisted of 92 individuals with cochlear dysfunction, 20 subjects with retrocochlear dysfunction, and 2 subjects with a combination of retrocochlear and cochlear disorder. Of the 92 subjects with cochlear lesion, 21 subjects presented a

Type I classification. Owens stated that the "continuous tracing shifts somewhat, but never breaks cleanly" (35, p. 459). He further indicated that the Type I Bekesy was generally produced by individuals with less severe hearing losses.

None of Owens' subjects diagnosed as having retrocochlear lesions produced a Type IV Bekesy. Type III Bekesy tracings were produced by subjects with retrocochlear lesions involving the eighth nerve. The subjects with both cochlear and retrocochlear involvement had hearing within normal limits, and one subject yielded a Type I Bekesy while the other produced a Type II category. Owens thus concluded that while a Bekesy audiogram of the Type III category may be one of the first diagnostic implications of eighth nerve damage, "Type I and Type II 'cochlear' patterns may occasionally camouflage an eighth nerve tumor" (35, p. 464).

From the investigation of current research reported concerning Jerger's types of Bekesy tracings it would appear reasonable to conclude that the classifications proposed by Jerger are valuable in indicating a particular site of lesion, but the investigator should not maintain the illusion that the classifications are absolute. The variability and range of abnormal as well as normal performance precludes the possibility of one hundred per cent categorization into one of the four categories.

The technique of Bekesy audiometry has been utilized for additional types of research which are not within the scope of the present study. It has been shown that Bekesy audiometry has been accepted as a useful clinical tool in determining auditory threshold sensitivity, auditory adaptation and fatigue, and predicting a site of lesion. Present investigation and clinical research support the contention that the technique of Bekesy audiometry is an important tool for clinical and diagnostic audiometry.

Tests Designed to Assess Central Auditory Function

Clinical audiometry has been more successful in the development of tests designed to differentiate between conductive and sensori-neural types of hearing impairment than in the development of tests to assess the central auditory apparatus (1, 26, 28). Routine clinical audiometry has not proved effective in detection of central auditory dysfunction (1, 6, 8, 9, 26), consequently, investigators have attempted to employ more complex or intricate testing stimuli in the evaluation of the primary auditory reception area of the cerebral cortex and in the pathways to the cerebral cortex.

To date, testing techniques involving the use of speech stimuli that are less easily recognized than speech stimuli used in conventional speech testing have proved more successful than tests employing variation of tonal presentations (7, 8, 26, 27, 28). Bocca (6, p. 302) states that information obtained by presentation of pure tones gives knowledge about the individual's hearing thresholds, but "it does not help in explaining how the cortex may elaborate the psychological aspects of a verbal message."

In 1954 Bocca and Calearo (9) presented one of the first distorted-speech techniques for testing individuals with temporal lobe tumors. The rationale for their test procedure was based on the theory that the integrative processes of the higher levels of the central auditory system were more readily challenged by speech stimuli that had a lower degree of redundancy, that is, stimuli that was more difficult to recognize.

The technique employed a low pass filter through which monitored speech was presented. The filter essentially eliminated the frequency components above 800 Hz. Individuals with normal hearing had bilaterally reduced discrimination, while the subject with an intercranial lesion showed poorer discrimination in the ear contralateral to the lesion.

In 1955 Bocca _et al_. (10) used lists of ten dissyllabic meaningless words with a low pass filter which eliminated the frequency components below 1000 Hz with eighteen patients diagnosed as having supratentorial cerebral tumors. Pure tone testing showed normal response levels, but the distorted speech test revealed lower scores in the ear contralateral to the lesion, in nearly all of the subjects. "In cases where the test gave negative results, surgery often confirmed that the tumors did not involve the auditory area of the temporal cortex" (10, p. 302). Bocca (7) stated in 1961 that the distorted speech method was too time consuming and that test results could be invalidated because of peripheral dysfunction.

Matzker (31) employed binaural fusion tests using two narrow band pass filters with speech signals transmitted through both filters. A low pass filter which attenuated frequencies below 500 Hz and above 800 Hz was utilized simultaneously to transmit a phonetic fragment of a test word to the right ear while the left ear received the remaining fragment of the test word filtered by a high frequency band, which eliminated frequency components below 1815 Hz and above 2500 Hz. Normal hearers had little or no difficulty with the test stimuli. Individuals with cerebral lesion showed a depressed score in the ear opposite the lesion, whereas individuals with brain-stem dysfunction showed a decreased score on the same side as that of the lesion. Matzker reported that the Binaural Fusion Tests had been administered to over 1700 patients and that he felt the results were promising. He felt that the synthesis of the stimuli occurred "within the brain stem where the two auditory pathways from either side are interconnected" (31, p. 1187).

In addition to distorted speech stimuli, the following types of speech messages have been employed with varying degrees of success in testing central auditory disorders.

(1) Interrupted voice. The speech message is periodically interrupted ten times per second. Individuals with

normal hearing generally score 80 per cent correct, while individuals with temporal lobe tumors have a reduced percentage correct (about 40 to 50 per cent) with a poorer score in the contralateral ear (8, 26).

(2) Accelerated voice: About 350 words per minute are delivered rather than the usual 150 words per minute. Normal subjects usually show an increase in threshold of about 10 to 15 dB, with 100 per cent discrimination. Individuals with central lesions also have a 10 to 15 dB threshold shift, but again, discrimination in the ear contralateral to the lesion is markedly reduced. The number of words per minute may also be decreased to a level less than the normal presentation with essentially the same results (8, 13, 26, 28).

(3) Supplementary messages: Meaningful speech messages are presented binaurally in a complicated manner. Correct response ability is related to binaural integration of the speech materials presented. Matzkers' (31) Binaural Fusion Test and tests which employ rapid message changes from ear-to-ear are examples of tests utilizing supplementary messages. The results for normals and for individuals with central lesions are essentially those reported for the preceding types of speech stimuli (8, 26, 28, 30, 31).

(4) Binaural competing message technique: The test involves presentation of overlapping of word stimulus. Individuals with normal hearing generally have a high percentage correct, while those individuals with central dysfunction show

a reduced score in the ear contralateral to the site of lesion (8, 13, 28).

SSW test. - - In 1962 Katz (27) proposed the use of binaural competing messages of partially overlapping spondaic words in evaluating the integration abilities of the central nervous system. In choosing the two-syllable spondaic word unit as the test stimulus Katz cited the works of Calearo and Lazzaroni (13) and Bocca (6) as indicating that more stable speech stimuli yield higher test reliability. He defined stable speech stimuli as "clear, familiar speech containing considerable redundancy" (27, p. 133). He states: "stable speech stimuli might provide greater certainty in diagnosis because of the likelihood of clear-cut normative data and relative resistance to associated or coincidental auditory deviations of a peripheral nature" (27, p. 329). In addition, speech material which is unstable may result in reduced test performance related to vocabulary and intelligence rather than central auditory dysfunction (1).

It is evident, then, that the most useful data can be obtained from speech stimuli which is not influenced by individual variables and which will not be affected by hearing losses due to peripheral distortion (1, 26, 27, 28). Because of the high correlation between speech reception thresholds obtained with spondaic words and pure tone thresholds even in the presence of cochlear lesion, the spondaic word is considered a stable speech stimulus (14).

The SSW test devised by Katz (27) uses four examples and forty test items, consisting of two familiar spondaic words per item. A third familiar spondaic word is formed by combination of the first syllable of the first word and the second syllable of the second word. For example, seashore and outside would form seaside. As previously stated, the test items are presented in a partially overlapping manner, so that presentation of the second syllable of the initial word and the first syllable of the second word overlap. A diagrammatic example would be as follows:

	Time Sequence 1	2	3
Right Ear	sea	shore	
Left Ear		out	side

Order of ear presentation is alternated so that the initial syllable of twenty items is presented to the right ear first and the first syllable of the remaining twenty items is presented to the left ear first.

To eliminate the percentage of error that could be attributed to peripheral or brain stem dysfunction, a Corrected Staggered Spondaic Word Score (CSSW) is also obtained. By subtracting the total percentage of correct answers for each specified ear condition and for each total ear score from the word discrimination score, errors which could be the result of a lesion outside the central hearing apparatus are avoided. The score is expressed in terms of percentage of error for each given ear condition and for the total ear score.

The SSW test appears to provide information of diagnostic value in clinical and experimental research. The test is still in the developmental stages in terms of widespread clinical usage for the detection of central auditory disorders, but research published to date indicates its potential as a worthwhile addition to a battery of clinical tests (1, 4, 26, 27, 28).

Results recorded by Katz (26, 27), Myrick (32), Balas (1), and Katz et al. (28) showed that individuals with normal hearing and conductive losses have a high percentage of correct responses on the SSW test. Subjects with peripheral lesions who exhibit a reduced percentage of correct scores generally can be differentiated from individuals with central lesions on the basis of three types of test behavior (1, 26, 27, 28): (1) Scores are bilaterally depressed: (2) reduced scores are present for non-competing stimuli as well as competing: and, (3) conventional word discrimination scores are reduced. Individuals with central lesions typically have reduced percentage scores for the ear contralateral to the site of lesion and more difficulty with the overlapping stimuli.

Berlin et al.(4) examined twenty patients with temporal lobectomies to determine their performance on a variety of special audiometric tests. They report that the SSW test consistently identified the excised lobe through laterality effects.

Myrick (32) administered a twenty-item test to a group of 50 normal children and 10 normal adults. Results indicate that as the chronological age increases, the number of errors decrease. Adult performance is obtained by the age of eleven years. Katz (26, 27) reports success with subjects as young as eight years, although results by Myrick (32), Turner (47), and Brunt (12) indicate that reliable results may not be attained with children as young as eight years of age.

In a study of 60 children between the ages of 8.0 years to 10.0 years having normal hearing and functional articulation disorders, Brunt (12) hypothesizes that the SSW test might aid in determining cerebral dominance for speech. He stresses the need for additional research to validate his results. A high percentage of error was characteristic for the subjects in his study.

An investigation by Turner (47) was designed to establish normative data for various age groups. Sixteen subjects in seven age groups from 9.0 years of age to 59.0 years of age were given the SSW test. Highest percentage correct scores in the adult groups were obtained by individuals in the twenty-year-old group, followed by the forty and fifty-year-old groups. A decrease in performance was found in the ten to eleven and ten to nine-year-old subjects.

Balas and Simon (2) established an articulation function curve which indicates that maximum test performance is obtained when the SSW test is presented at 50 dB sensational level above the speech reception threshold.

Summary

The principles involved in Bekesy type audiometry and methods of assessing central auditory integrity were reviewed. The unexplained atypical Type I Bekesy behavior of some individuals with cochlear lesion and the possibility that the SSW test could provide quantitative information concerning that behavior were introduced. The significant features of the SSW test were discussed.

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CHAPTER II

SUBJECTS, APPARATUS, DESIGN AND PROCEDURE

Subjects

Control Group

Ten subjects between the ages of 18 and 29 years, having a mean chronological age of 24.1 years and hearing loss levels no greater than 5 dB, composed the control group or Group N of the study. The subjects were students at North Texas State University in Denton, Texas, and were selected on the basis of availability. No significant otologic or neurologic history was reported by any member of the control group as determined through answers received on a hearing case history of each subject.

Experimental Population

The experimental population consisted of 55 adult males between the ages of 19 to 59 years. The mean chronological age for the group was 42.7 years. The subjects were chosen from service veterans given routine audiometric assessment at the Veterans Administration Hospital in Dallas, Texas.

The pure tone audiogram of each subject showed no gap between air conduction and bone conduction scores, thus presenting a characteristic audiometric pattern for a cochlear hearing disorder or normal hearing.

Each subject had been examined in the Ear, Nose, and Throat Clinic at the Veterans Hospital. No individual having an active disorder of the middle or outer ear, perforation of the ear drum, history of central nervous system disorders or head injury, or a history of excess use of medication was included in the study.

In view of previous investigations (3, 6), it was anticipated that at least one-fifth and no more than one-fourth of the subjects presenting a sensori-neural type of hearing impairment would exhibit a Type I Bekesy tracing. The rest presumably would exhibit the characteristic Type II pattern. Therefore, the first 15 subjects presenting a Type I Bekesy pattern comprised Group I, the primary group investigated in the study. For purposes of comparison, 15 subjects tracking a Type II Bekesy tracing were selected as the second experimental group, Group II. Group II subjects were selected from the total experimental population on the basis of availability.

Classification of the two types of Bekesy tracking behavior for the subjects in each of the two groups was made independently by two judges. If one hundred per cent agreement was not reached as to the classification of the tracing represented, the subject was not used in the study.

Apparatus

Each of the tests utilized in the study was administered through standard audiometric equipment. Group N was tested at North Texas State University Speech and Hearing Clinic. The experimental population was tested at the Veterans Administration Hospital in Dallas, Texas. Identical equipment and testing environments were available in both clinical testing situations. Apparatus used in both clinical environments were regularly calibrated to International Standards for Audiometric Zero (1964) with a Bruel & Kjaer Model 2103 sound level calibration unit. The Short Increment Sensitivity Index (SISI) accessory unit on the Beltone 15 CX audiometer was also calibrated regularly at the Veterans Hospital.

The following equipment was used in the test functions as indicated:

(1) All test measurements were conducted in double-walled Industrial Acoustics Company sound suites.

(2) Each of the testing instruments was provided with TDH-39 earphones with MX 41/AR cushions.

(3) All pure tone testing was administered through a Beltone 15 CX audiometer. The SISI accessory unit on this audiometer was used to conduct the SISI test.

(4) The speech reception threshold and word discrimination score for each subject were determined through a Grason-Stadler Model 162 dual channel speech audiometer.

(5) The Bekesy test was given with a Grason-Stadler Bekesy Audiometer Model E-800-4.

(6) For the administration of the SSW test a 7½ millimeter SSW tape was channeled through an Ampex dual channel tape recorder Model 602 to the Grason-Stadler Speech Audiometer Model 162.

Design

Group N

Control subjects were administered a screening hearing test for bilateral auditory sensitivity at 5 dB intensity level at frequencies 250, 500, 1000, 2000, 4000 and 8000 Hz. Group N also received the SSW test. It was assumed that the speech reception threshold was "0" dB or better (5). The control group was included in the present study to further confirm the low percentage of error reported by Katz (5) for normal hearers with the SSW test.

Experimental Group

A diagnostic audiometric test battery was given to each subject to aid in the confirmation of the cochlea as a site of lesion. The following measurements were taken for each subject in the total experimental population: speech reception threshold, word discrimination score, pure tone air and bone conduction thresholds, and sweep-frequency Bekesy with interrupted and continuous tone tracings. In addition, the 30 subjects classified as members of Group I and Group II received the SISI test and SSW test.

Procedure

Speech Reception Threshold

Live-voice speech reception threshold scores were obtained through presentation of Harvard spondee word lists. The words were initially presented at a level 15-20 dB above the estimated hearing threshold. The intensity of the presentation was decreased in 2 dB steps until the subject failed to repeat three out of a series of six spondaic words. A level of 2 dB above the intensity at which the subject failed fifty per cent criterion was recorded as the individual's speech reception threshold or the level at which fifty per cent of the words presented were correctly repeated by the subject. Testing time was about ten minutes.

Word Discrimination Score

Live voice word discrimination lists of fifty phonetically balanced words were administered at a comfortable listening level determined by the evaluation of the subject. Hirsh's (2) list of phonetically balanced words was utilized in the present study. The recorded score was the percentage of correct responses of the fifty items presented. Testing time was approximately thirty minutes.

Pure Tone Tests

In the administration of pure tone audiometric testing, the standard Hughson-Westlake clinical procedure as revised in 1959 by Carhart and Jerger (1) was followed. The recorded relative threshold represented fifty per cent correct response at a single intensity level for a given frequency. Testing time was approximately thirty minutes.

Bekesy

A sweep frequency Bekesy from 250 Hz to 10000 Hz was obtained on both ears of each subject. As a result of the Bekesy test, absolute threshold values at all frequencies from 250 Hz to 10000 Hz were available. A classification into one of the two major categories applicable to the study was also made on the basis of the relationship between the interrupted and continuous tone tracings as determined by Jerger's classification system (3).

Type I Bekesy tracings represented an interweaving of the continuous and interrupted tone tracings with a difference of less than 10 dB between the thresholds for the two types of tracings through the entire frequency range tested. Type II tracings were recorded when a 10 dB or greater shift between the interrupted and continuous tone was present. In all of the Type II subjects used in the present study, the shifts occurred above 1000 Hz.

Thresholds were interpreted as the mid-line point between the upper and lower limits of the tracing peaks at a given frequency for the interrupted tone tracing.

The Grason-Stadler Bekesy Audiometer Model E-800-4 provided a three position adjustment for calibration of the intensity of the masking source, the stimulus intensity, and the frequency of the stimulus presentation. Prior to each testing session, the three-step calibration was made in accordance with specified levels (3). The "slow" table or motor speed for each test was utilized with a travel time of six and two-thirds minutes for 100 Hz to 10000 Hz. Attenuation rate was 2.5 dB per second. The rate of frequency change was one octave per minute. The presentation rate for the pulsed tone was 2.5 dB pulses per second. Testing time was approximately thirty minutes.

The interrupted tone was always presented before the continuous tone. The following test instructions were given to each subject prior to presentation of the interrupted tone:

> When I put these earphones on, you are going to hear a beeping sound in your ear. As long as you don't do anything the sound will keep getting louder. But you can make it fade away by holding down this switch. When you let up on the switch the sound will get louder again. Now, here is what I want you to do. Listen very carefully, and, as soon as you hear the beeping sound, hold this switch down until you can't hear it any more. As soon as the beeping sound is gone, let up on the switch until it comes back. Then, as soon as you hear it again, hold the switch down until it goes away again, and so forth. Never let the sound get very loud and never let it stay away too long. Hold this switch down as soon as you hear the sound, then let up as soon as the sound is gone (3, p.277).

A tracing was then made with the interrupted tone stimulus. The continuous tone was presented after the subject received the following instructions:

> Now we are going to do the same thing again, but this time the sound will be steady instead of beeping on and off. Your job is still the same. Hold the switch down as soon as you hear the steady sound, and let it up as soon as the steady sound goes away (3, p. 277).

Short Increment Sensitivity Index

The SISI test was designed to determine if an individual could distinguish very small changes in sound intensity. Jerger states:

> If the disorder is in the cochlea, then the patient will be able to hear changes smaller than the normal ear can hear. This curious ability to hear very small intensity changes apparently occurs only when the disorder is in the cochlea, not when it is in the middle ear or in the eighth nerve (3, p. 139).

The SISI test was utilized in the study to identify more positively the cochlea as the site of lesion in the subjects composing the two experimental groups. The frequencies tested were 1000 Hz, 2000 Hz, and 4000 Hz. The subject listened to a steady tone 20 dB above the threshold for a given frequency for about two minutes. The tone shifted in intensity for 200 milliseconds, with a rise-and-fall time of 50 milliseconds.

The test involved a total of twenty-eight presentations for each frequency tested. A series of five 5-dB shifts or brief increases in intensity was introduced to alert the subject to the phenomena for which he was listening. Presentations for the recorded score consisted of twenty shifts in intensity at 1 dB increments for each frequency being tested. Interspersed between every five presentations were three additional presentations. To prevent the individual from adapting to the time pattern of intensity changes presented, the increment dial was decreased to "0" dB after each series of five presentations at 1 dB increments if the subject responded to at least three out of five shifts in intensity. To re-orient the subject to the acoustic product of the stimulus, the increment dial was turned to the 5 dB increment level if the subject responded to fewer than three of the five intensity changes at 1 dB increments.

The recorded performance was determined by the percentage of the 20 intensity changes at 1 dB increments to which the subject responded. A positive SISI score indicated that the subject had responded to at least sixty per cent of the increment changes. Negative SISI scores were recorded when the individual responded to fewer than twenty per cent of the presentations. A questionable score was recorded if the individual heard thirty to sixty per cent of the intensity shifts.

Individuals with normal hearing, outer or middle ear pathology, or eighth nerve disorders generally hear fewer than twenty per cent of the shifts at all frequencies (4). Individuals having cochlear pathology generally score above sixty per cent at frequencies over 1000 Hz (4).

Testing time was approximately fifteen minutes. Prior to testing, the following instructions were given to each subject:

> You will hear a steady sound in your ear for about ten minutes. The sound will be very faint. During the time it is on you may occasionally hear a little jump in loudness. Whenever you are quite sure that you have heard one of these loudness jumps, raise your hand. If you think that you heard a jump; but you are not certain, then do not raise your hand, only raise it when you are sure you heard a jump in loudness (4, p.139).

Staggered Spondaic Word Test

The SSW test was primarily designed to aid in the detection of central nervous system disorders. However, certain patterns of scores have emerged as characteristic of individuals with normal hearing, conductive losses, and sensori-neural losses as well as those patterns associated with central lesions. While individuals with normal hearing and conductive losses reportedly missed relatively few items on the test (5), those individuals with sensori-neural losses in conjunction with a reduced word discrimination score produced a higher percentage of incorrect responses on the SSW test. Individuals with central lesions typically did not have a reduced word discrimination score as reported by Katz (5), although they had a lower percentage correct response on certain ear conditions of the SSW test bilaterally for competing and noncompeting messages. Individuals with central lesions have not shown significant difficulty with noncompeting messages in the ear contralateral to the side of the lesion (5).

List EC-40 of the SSW test was administered binaurally at a presentation level of 50 dB above the speech reception threshold score of each subject in the manner suggested by Katz (5). The SSW tape was provided with a 1000 Hz calibration tone. Before each administration of the test, both channels of the speech audiometer were adjusted with the 1000 Hz tone so that the VU meter was peaked at "0". This adjustment provided presentation of the SSW test at accurate sensation levels for each channel of the speech audiometer.

Subjects were alternated as to the order of ear presentation to insure that ear order patterning would not affect the over-all validity of the results. Four examples were given prior to the actual test items.

The test items consisted of forty pairs of spondaic words. If the first monosyllable of the first spondaic word and the last monosyllable of the second spondaic word were combined, a third familiar spondaic word was formed. For example, <u>cornbread</u> and <u>oatmeal</u> formed a third familiar spondaic word, <u>cornmeal</u>. For each test item, the second syllable of the first word and the first syllable of the second word were presented in overlapping fashion. As described in Chapter I, each test item was constructed so that the subject listened first to a single item on one side, then to an overlapping item binaurally, and finally to a single item monaurally.

The subject responded to each test item by repeating the group of words that he heard. When responses were unintellegible to the clinician, clarification was obtained through repetition by asking the subject to repeat his response. Responses of each subject were tallied according to the number of errors for each ear condition, for the total ear condition, and for the total binaural percentage of correct response. Error types were omission, substitution, or distortion of any of the four monosyllables in a test item. The four ear conditions were as follows: (1) single word messages transmitted to the right ear without a competing message in the opposite ear (RNC); (2) single word messages transmitted to the right ear with a competing stimulus in the opposite ear (RC); (3) single word messages transmitted to the left ear without a competing message in the opposite ear (LNC); and (4) single word messages transmitted to the left ear with a competing stimulus in the opposite ear (LC).

To eliminate the percentage of error attributable to lesions involving the peripheral mechanism or the brain stem, a CSSW was obtained to determine the percentage of error for each given ear condition and for the total ear score. The total percentage correct response score for each specified ear condition and for the total ear score. The total percentage correct response score for each specified ear condition and for each total ear score was subtracted from the word discrimination score. All scores computed were reported on the response scorring form in Appendix A. Total testing time was twenty minutes.

Prior to testing, the following instructions were given to each subject:

> You are going to hear some words which will be presented to one or both of your ears. The words will be presented in small groups. Just as soon as the group of words is completed, I would like you to repeat them all back to me. Take a guess if you are not quite sure of a word. Before each item you will hear the phrase, 'Are you ready?' Please don't repeat this phrase, just the group of words that follow it (5, p.134).

Summary

Twenty subjects having normal hearing and no significant otologic or neurologic history were given an audiometric screening test at 5 dB intensity level and a SSW test at 50 dB dial setting. The control group was used to validate the efficacy of the SSW test with a normal hearing population. Testing was administered in an isolated sound suite with calibrated audiometric equipment at the North Texas State University Speech and Hearing Clinic in Denton, Texas.

A diagnostic test battery was utilized in selecting an experimental population of individuals with sensori-neural hearing impairment. All subjects were examined by a physician in the Ear, Nose, and Throat Clinic at the Veterans Administration Hospital in Dallas, Texas, and were cleared for use in the study in that there was no perforation of either ear drum or active outer or middle ear pathology. Two groups of 15 subjects were administered tests to determine the following measurements: speech reception threshold, word discrimination score, pure tone air and bone conduction thresholds, Bekesy tracing pattern, SISI scores, and SSW test scores. Patients producing a Type I Bekesy comprised the primary group investigated, with patients producing a Type II Bekesy utilized for comparative purposes between test performances of the two groups.

All testing was conducted in a sound-treated test suite with calibrated audiometric equipment at the Veterans Administration Hospital in Dallas, Texas. Total testing time was approximately two hours for each subject in the two experimental groups. Ten-minute rest intervals were provided after the administration of the speech and pure tone test, and again after the administration of the Bekesy test.

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CHAPTER III

RESULTS AND STATISTICAL TREATMENT

Results

Group N

Ten normal subjects, Group N, having hearing levels of 5 dB or better and no reported history of ear pathology or known central nervous system dysfunction were given the SSW test. The average total percentage correct score was 98.9 per cent, which was found to correlate with Katz' (1) total correct score of 98 per cent for individuals with hearing within normal limits.

Total Experimental Group

A total of 55 subjects were administered audiometric tests to determine the speech reception threshold, word discrimination score, and pure tone air and bone conduction thresholds. A sweep frequency Bekesy tracing from 250 Hz to 10000 Hz, utilizing interrupted and continuous tone tracings, was also obtained for both ears of each subject.

All 55 subjects were examined in the Ear, Nose, and Throat Clinic at the Veterans Administration Hospital in Dallas, Texas. There was no reported evidence of active middle or outer ear pathology or history indicative of dysfunction associated with central nervous system disorders.

Experimental Population

Bekesy. - - Fifteen of the 55 subjects presented a Type I Bekesy tracing. These subjects represented 27 per cent of the total experimental population and comprised Group I. The remaining 40 subjects traced a Type II Bekesy pattern. These subjects represented 73 per cent of the total experimental population. Fifteen of the 40 subjects were selected on the basis of availability to form Group II.

SISI. - - The study population was administered the SISI test at 1000 Hz, 2000 Hz, and 4000 Hz. All SISI scores for Group I at 1000 Hz were negative, five scores at 2000 Hz were positive, and twelve scores at 4000 Hz were positive. Two SISI scores were positive at 1000 Hz for Group II subjects. Ten scores at 2000 Hz were positive, and thirteen scores at 4000 Hz were positive.

Speech reception threshold, word discrimination score, and pure tone air and bone threshold measurements. - - Table I summarizes the results of speech intelligibility tests and pure tone tests for subjects in Group I and Group II. Examination of Table I reveals that the average speech reception threshold score for Group I was 9.6 dB for the right ear and 10.5 dB for the left ear. Word discrimination averages were 98.3 per cent for the right ear, with a mean of 96.1 per cent for the left ear. The pure tone average for the speech frequencies, 500 Hz, 1000 Hz, and 2000 Hz, was 13.2 dB and 15.1 dB for the right and left ears, respectively.

TABLE I

SPEECH RECEPTION THRESHOLDS, WORD DISCRIMINATION SCORES AND PURE TONE AVERAGES

Group	SRT*		WDS**		PTA***	
	Right	Left	Right	Left	Right	Left
I	9.6	10.5	98.3	96.1	13.2	15.1
II	14.3	16.4	91.6	95.6	19.7	21.2

*Speech Reception Threshold; **Word Discrimination Score; ***Pure Tone Average.

The average speech reception threshold for the subjects comprising Group II was 14.3 dB for the right ear and 16.4 dB for the left ear. The word discrimination average was 91.6 per cent for the right ear and 95.6 per cent for the left ear. A pure tone mean of the speech frequencies for the right ear was found to be 19.7 dB, while the left ear average was 21.1 dB.

SSW test. --The SSW test results in relation to the mean performance for each of the two groups are presented in Table II. Scores are reported in terms of number of errors, total percentages correct, and CSSW scores (that is, adjusted percentages of error) in terms of the four ear conditions and average performance for each ear.

The total number of errors by an individual in Group I ranged from 1 incorrect response to 38 incorrect responses. The average total number of errors was 6.5 words missed. For Group II subjects the total number of errors in terms of individual performance ranged from 2 to 44 incorrect answers. The average total number of errors of missed words was 7.8 for the entire group.

TABLE II

SSW RESULTS

	Right Ear NC*	Right Ear C**	Average	Left Ear NC	Left Ear C	Average
Percentage Correct						
Group I	93.7	89.5	91.6	94.5	89.7	92.1
Group II	93.5	86.8	90.2	93.3	87.1	90.2
CSSW						
Group I	4.5	8.8	6.7	3.7	5.6	4.6
Group II	4.8	11.5	8.1	2.3	7.1	4.7
Total Number of Errors						
Group I	2.3	4.2	6.5	2.1	4.0	6.1
Group II	2.6	5.2	7.8	2.8	4.5	7.3

*Noncompeting; ** Competing

The highest individual total per cent correct score in Group I was 99 per cent, while the lowest score was 81 per cent. The mean total percentage correct score was 91.9 per cent. In Group II, the highest percentage correct score was 99 per cent, with the lowest being 73 per cent correct. An average of 90.2 per cent correct represented the performances of Group II subjects.

CSSW scores for Group I showed a range from 0 to 41 percentage of error, with an average of 6.7 per cent for the group as a whole in terms of right ear performance. The lowest corrected score for the left ear was -7 per cent, while the highest score was 22 per cent error. The average CSSW score for the left ear was 4.6 per cent incorrect response. For Group II subjects, the total right ear score average was 8.1 per cent, with a range from -4 to 24 per cent error. In the left ear, scores ranged from 0 to 13 per cent incorrect response, with an average of 4.7 per cent incorrect response.

In examination of individual performance for the CSSW scores, one subject in Group I indicated moderately abnormal dysfunction for the right ear noncompeting and competing conditions as determined by the criteria suggested by Katz (1). Scores for the left ear were within normal limits. Word discrimination scores were 96 per cent in the right ear and 100 per cent in the left ear, so the speech discrimination score did not account for a reduced score because of peripheral distotion. A second individual in Group I had depressed left ear scores of mildly abnormal level. Scores for the right ear were within normal limits. Group II had two subjects with mildly abnormal depressed scores for the right ear and scores within normal limits for the left ear. Each of the four subjects described exhibited difficulty with competing and noncompeting message conditions for the ear, which produced a high percentage of error. Typically, individuals with "pure" central auditory lesions exhibit more difficulty with the competing message rather than both types of messages (1). Additional testing would appear to be indicated to determine the significance of the results for the individuals exhibiting deviant CSSW scores.

Seven individual ear condition scores from both groups were between 16 per cent and 25 per cent error, which Katz (2) specified as not being characteristic of a normal listener, although not deviant enough to indicate significant impairment. According to Katz (1, p. 139), "such an individual falls into the central nonauditory category provided that his hearing for speech is normal. At present we do not know what SSW results are obtained when a patient has a central nonauditory lesion as well as hearing loss in the speech range."

An investigation of the error total of each independent test syllable was also made. Twenty-four of the 160 syllables were repeated correctly by all the subjects. The syllables most frequently missed were meat, sauce, boy, cup, land, and give. Total number of errors for these syllables ranged from ten to seventeen times missed. The number of errors for the remaining items were spaced from 1 to 8 times missed. It would appear that some of the word items were more readily identified than others.

Statistical Treatment

The Mann-Whitney U Test was used to determine if significant differences in test scores between the two groups were in evidence. The Mann-Whitney U test was chosen for the analysis procedure because there was reason to doubt the normality of the groups, and the resultant non-parametric data were distribution-free. A high degree of reliability has been reported with this procedure and it has been suggested as a powerful alternative to the parametric t test (2).

The test scores used for analysis were ranked from the highest to the lowest score as though the scores were all in one group. The U value was then obtained by using the scores of the lower ranked group to compute the number of scores in the higher ranked group which fell below the lower ranked group. For example, if the scores of the lower ranked group were all below the scores of the higher ranked group, the U value would be zero. To be significant at the 0.05 level, thus rejecting the null hypothesis, the U value for the present study would have to have been less than 64. The lower the obtained value of U, the more significant the result.

Values of U were obtained for the four ear categories, average ear totals, and combined ear scores for total percentage correct scores and for total number of errors. U values for the CSSW scores for the four ear classifications and average ear scores were also computed.

Table III presents the U values for each of the measures analyzed in the study. Examination of Table III reveals that all U values were in excess of 64; therefore, the null hypothesis at the 0.05 level of significance would be tenable for all results obtained.

TABLE III

SSW U VALUES

Right Ear NC	Right Ear C	Ear Total	Left Ear NC	Left Ear C	Ear Total	Combined Score
Total Percentage Correct						
105	94	91	96	95	94	95
Total Number of Errors						
97	91	100	94	104	101	107
CSSW						
104	75	92	103	72	85	

Summary

Results of the test measurements utilized in the current study have been presented. Statistical evaluation of the raw data from the SSW test was computed for each of the four ear categories and average ear scores for the total number of errors, total percentage correct, and CSSW scores. In addition, evaluation of combined scores for both ears was made for total number of errors and total percentage correct.

A wide range of individual scores was observed. Analysis of SSW test performance revealed no significant difference between the two groups at the 0.05 level of significance, thus leading to acceptance of the null hypothesis for all results obtained.

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CHAPTER IV

DISCUSSION, CONCLUSIONS, AND SUMMARY

Discussion

Study Population

Discussion of the test results for the study population will be presented in the same order in which the results and statistical evaluation were given in Chapter III.

Bekesy. -- Percentage representation of Types I and II, 27 per cent and 73 per cent respectively, correlated with the expected one-fifth to one-fourth Type I population observed in the investigations of Jerger (1) and Owens (2).

SISI. -- SISI scores were positive when the frequency threshold was above 40 dB *re* International Standards for Audiometric Zero (1964). The positive SISI scores strengthened identification of the cochlea as the site of lesion in the subjects utilized in the current study.

Speech reception threshold, word discrimination score, and pure tone air and bone threshold. -- Group I scores were slightly better in terms of speech reception threshold and pure tone threshold averages, with slightly increased percentages correct means for discrimination percentages. Although the average score of the test measurements indicated a trend toward better test performance for Group I subjects, the differences were numerically small and could not be considered significant in terms of their influence on SSW test performance.

<u>SSW Test</u>. - - SSW test results, with the exception of the CSSW score for the left ear noncompeting message, revealed a lower percentage of error, or better test performance, for Group I. Again, the differences between independent SSW scores for the two groups were relatively small in all instances despite slightly superior performance by Group I subjects as a whole.

In terms of correlation between average per cent reduction of the word discrimination score and the CSSW per cent of error for Group I, the right ear percentage mean was 1.7 per cent for the discrimination score and 6.7 per cent for the CSSW score. Left ear error percentages for discrimination and CSSW scores were 3.9 per cent and 4.6 per cent, respectively. These scores indicate that the relation between the SSW correction factor and the resultant scores for the group as a whole were more closely correlated for the left ear scores.

CSSW scores for Group II were closer to word discrimination error percentages in terms of numerical value. Discrimination averages for the right and left ears were 8.4 per cent and 4.4 per cent, while CSSW scores for the right ear were 8.1 per cent and 4.7 per cent for the left ear.

The adjusted factor for determining CSSW scores for group performance obtained in the present study did reduce the degree of error attributable to peripheral distortion for the majority of the subjects utilized.

Statistical Treatment

Analysis of SSW test performance between the two groups revealed no significant differences for any of the measures computed. U values computed for the competing messages in the right and left ears indicated that there was a greater likelihood of significance for these two conditions in terms of CSSW performance, but the obtained values were still in excess of the required level of significance.

Conclusions

It may be concluded that

1. Approximately one-fourth of the individuals having apparent sensori-neural dysfunction will produce a Type I Bekesy pattern that is characteristically associated with normal hearing and conductive pathology.

2. Although the numerical difference is small, individuals who trace a Type I Bekesy pattern in the presence of cochlear involvement may tend to have slightly superior test performance on speech intelligibility tests and pure tone air and bone threshold tests than do individuals with cochlear involvement who trace a Type II Bekesy.

3. The SSW test of sequential patterning did not reveal differential information about the test behavior of individuals tracking a Type I Bekesy in the presence of sensori-neural involvement.

4. The explanation for atypical Type I Bekesy behavior was not accountable through analysis of the test measurements utilized in the present study.

Future research would appear to be most worthwhile that concentrated on extensive exploration of SSW test merit in regard to acceptable performance of varied age groups and performance of individuals with deviant speech or hearing behavior. While some research has been reported in the areas previously mentioned, further validation is needed. An analysis of the relative familiarity of the test items and the subsequent effect on SSW test performance appears to be warranted.

Summary

The present study was designed to determine if significant audiometric characteristics existed in a group of individuals having cochlear lesions who traced a Bekesy pattern characteristic of individuals with normal hearing or conductive losses. The following questions were utilized in investigation of the problem: (1) Does the SSW test of sequential patterning reveal differential information about the individual having a sensori-neural hearing disorder as established by a battery of audiometric tests but tracing a Type I Bekesy pattern? (2) Do individuals tracing a Type I Bekesy pattern who otherwise present evidence of cochlear involvement perform differently on the SSW test from those individuals exhibiting a Type II pattern in the presence of a sensori-neural impairment?

Ten subjects with a mean age of 24.1 years and having hearing levels of 5 dB or better and no reported history of conductive pathology or central nervous system dysfunction were given the SSW test. These subjects were tested at North Texas State University Speech and Hearing Clinic in Denton, Texas. The group achieved a mean percentage of 98.9 per cent correct response which supported data indicating that normal subjects have relatively little difficulty with the SSW test.

The experimental population was chosen from service veterans receiving routine audiometric assessment at the Veterans Administration Hospital in Dallas, Texas. A total of 55 subjects with a mean age of 42.7 years comprised the experimental population. All 55 subjects presented evidence of apparent cochlear involvement as determined by an otological examination and results of a series of audiometric measurements. Each subject was administered tests to determine the following: speech reception threshold, word discrimination score, and pure tone air and bone conduction thresholds.

Fifteen subjects in the total experimental group traced a Type I Bekesy and represented Group I. Fifteen subjects who produced a Type II pattern were selected on the basis of availability from the remaining experimental population to form Group II. In addition to the testing battery previously mentioned, subjects in Groups I and II were given the SISI test and the SSW test.

Examination of test performance for the two groups indicated that Group I subjects consistently had better test results, although actual measurement differences were small between the two groups. Statistical analysis of the SSW test scores revealed no significant differences at the 0.05 level, thus accepting a null hypothesis value. Therefore, it was concluded that the SSW test did not provide quantitative information about Group I subjects who traced a Type I Bekesy pattern in the presence of apparent sensori-neural involvement.

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APPENDIX A

The following five pages present a copy of the scoring sheet and word test items utilized in administration of the Staggered Spondaic Word Test.

Name ________________ Date ______________ S#______________

Age ______ Sex ______ Group ______ List __E-C__ 1st Ear ________

CORRECTION SCORES

(R-WDS) - (R-NC) ______-______=______

(R-WDS) - (R-C) ______-______=______

(R-WDS) - (TOT R) ______-______=______

(L-WDS) - (L-C) ______-______=______

(L-WDS) - (L-NC) ______-______=______

(L-WDS) - (TOT L) ______-______=______

ENTER THE TOTAL NUMBER OF ERRORS HERE

A. R-NC: ______x(   )=100-______=______% correct

B. R-C: ______x(   )=100-______=______% correct

C. L-C: ______x(   )=100-______=______% correct

D. L-NC: ______x(   )=100-______=______% correct

E. TOT R: (A+B number errors)_____x(   )=100-_____= _____% correct

F. TOT L: (C+D number errors)_____x(   )=100-_____= _____% correct

G. TOT SSW: (A, B, C, D number errors) _____x(   )=100-_____ =_____% correct

TO GET % ERROR MULTIPLY BY:

#ITEMS	MONOSYL	TOT EAR	TOT SSW
20	5	2.5	1.25
25	4	2	1
40	2.5	1.25	.63
50	2	1	.5
52	1.9	.96	.48
60	1.7	.83	.42

PURE TONE AND SPEECH SUMMARY

	1-kc	S.A.	SRT	WDS	BC@1	SSW LEVEL
RE						
LE						
M						

ORDER________; EAR________; PATTERN________; TRUE=________

PART=________ REVERSALS=________

SSW TEST

LIST E-C

Right Ear First ______________ Name ______________________
(A=R-NC, B=R-C etc.) S#__________ Group __________
Left Ear First ______________ Age _________ Sex ___________
(A=L-NC, B=L-C etc.)

	L-NC A R-NC	L-C B R-C	R-C C L-C	R-NC D L-NC		R-NC E L-NC	R-C F L-C	L-C G R-C	L-NC H R-NC	No. WRONG
1.	up	stairs	down	town						
					2.	out	side	in	law	
3.	day	light	lunch	time						
					4.	wash	tub	black	board	
5.	corn	bread	oat	meal						
					6.	bed	spread	mush	room	
7.	flood	gate	flash	light						
					8.	sea	shore	out	side	
9.	meat	sauce	base	ball						
					10.	black	board	air	mail	
TOTAL										

	L-NC A R-NC	L-C B R-C	R-C C L-C	R-NC D L-NC		R-NC E L-NC	R-C F L-C	L-C G R-C	L-NC H R-NC	NO. WRONG
11.	house	fly	wood	work						
					12.	green	bean	home	land	
13.	sun	day	shoe	shine						
					14.	white	walls	dog	house	
15.	back	door	play	ground						
					16.	school	boy	church	bell	
17.	snow	white	foot	ball						
					18.	band	saw	first	aid	
19.	blue	jay	black	bird						
					20	ice	land	sweet	cream	
TOTAL										

	L-NC A R-NC	L-C B R-C	R-C C L-C	R-NC D L-NC		R-NC E L-NC	R-C F L-C	L-C G R-C	L-NC H R-NC	NO. WRONG
21.	hair	net	tooth	brush						
					22.	fruit	juice	cup	cake	
23.	ash	tray	tin	can						
					24.	nite	light	yard	stick	
25.	key	chain	suit	case						
					26.	play	ground	bat	boy	
27.	corn	starch	soap	flakes						
					28.	birth	day	first	place	
29.	day	break	lamp	light						
					30.	door	knob	cow	bell	
TOTAL										

	L-NC A R-NC	L-C B R-C	R-C C L-C	R-NC D L-NC		R-NC E L-NC	R-C F L-C	L-C G R-C	L-NC H R-NC	NO. WRONG
31.	bird	cage	crow's	nest						
					32.	week	end	work	day	
33.	book	shelf	drug	store						
					34.	wood	work	beach	craft	
35.	hand	ball	milk	shake						
					36.	fish	net	sky	line	
37.	for	give	milk	man						
					38.	sheep	skin	bull	dog	
39.	race	horse	street	car						
					40.	green	house	string	bean	
Total (p.4)										
p.3										
p.2										
p.1										
Grand Total										
	R-NC L-NC	R-C L-C	L-C R-C	L-NC R-NC		L-NC R-NC	L-C R-C	R-C L-C	R-NC L-NC	

TESTER ____________________

COMBINED:			
R-NC	R-C	L-C	L-NC

APPENDIX B

The following two pages present raw data for the thirty subjects comprising Group I and Group II. The following test scores are reported: speech reception threshold (SRT); word discrimination score (WDS); pure tone air and bone average for 500, 1000, and 2000 Hz (PTA); SISI results for 1000, 2000, and 4000 Hz; and SSW scores in terms of total number of errors, percentage correct, and CSSW scores for right ear noncompeting messages (RNC), right ear competing messages (RC), left ear noncompeting messages (LNC), left ear competing messages (LC), and average scores for both ear totals.

The subjects were numbered in the order of their selection for one of the two experimental groups.

GROUP I

Subject	Age	SRT		WDS		PTA		SISI					
		RE	LE	RE	LE	RE	LE	RE			LE		
								1k	2k	4k	1k	2k	4k
1	47	6	8	100	100	7	8	-	-	+	-	-	+
2	37	30	22	96	100	42	33	-	+	+	-	+	+
3	28	18	14	100	100	18	15	-	-	-	-	-	-
4	51	20	26	100	96	25	32	-	-	+	-	-	+
5	23	2	2	100	100	3	2	-	-	+	-	-	+
6	51	6	8	100	96	10	12	-	-	+	-	-	+
7	56	10	8	94	88	13	12	-	-	+	-	-	+
8	45	6	8	96	90	10	7	-	-	+	-	-	+
9	59	4	4	100	100	7	7	-	-	+	-	-	+
10	22	0	2	96	100	0	0	-	-	+	-	-	+
11	38	8	6	100	100	8	8	-	-	+	-	-	-
12	52	10	10	96	96	12	23	-	-	+	-	-	+
13	22	6	8	100	82	12	27	-	-	+	-	+	+
14	45	8	18	100	96	7	17	-	-	+	-	-	+
15	27	10	14	96	96	23	23	-	+	+	-	+	+

GROUP II

1	40	8	4	100	100	8	3	-	-	+	-	-	+
2	48	10	6	100	100	13	8	-	-	+	-	-	+
3	49	18	18	94	94	27	27	-	+	+	-	+	+
4	54	22	18	98	100	27	27	-	-	+	-	-	+
5	40	0	2	100	100	2	0	-	-	+	-	-	+
6	40	0	4	100	100	3	12	-	-	+	-	-	+
7	41	8	16	100	98	20	22	-	-	+	-	-	+
8	47	4	8	100	98	13	22	-	-	-	-	-	+
9	46	22	10	100	100	22	10	-	-	+	-	-	+
10	49	26	24	100	100	35	28	-	+	+	-	+	+
11	54	20	20	100	100	23	22	-	+	+	-	-	+
12	54	18	50	86	68	32	52	-	+	+	+	+	+
13	27	32	44	100	94	37	48	-	+	-	+	+	+
14	52	14	14	96	82	20	30	-	-	+	-	+	+
15	43	12	8	100	100	13	10	-	-	+	-	-	+

SSW SCORES

Group I

S*	Total No. of Errors						Total % Correct						CSSW					
	RNC	RC	AV	LNC	LC	AV**	RNC	RC	AV	LNC	LC	AV	RNC	RC	AV	LNC	LC	AV
1	0	0	0	0	1	1	100	100	100	100	98	99	0	0	0	0	2	1
2	15	21	36	0	2	2	60	50	55	100	95	98	36	46	41	0	5	3
3	0	1	1	0	1	1	100	97	99	100	97	99	0	3	2	0	3	2
4	1	4	5	1	4	5	97	90	94	97	90	94	3	10	7	-1	6	3
5	1	1	2	1	1	2	97	97	97	97	97	97	3	3	3	3	3	3
6	5	6	11	6	6	12	87	85	86	85	85	85	14	15	14	11	11	11
7	1	4	5	0	4	4	97	90	94	100	90	95	-3	4	1	-12	-2	-7
8	3	2	5	10	15	25	92	95	94	75	62	79	4	1	3	15	28	22
9	0	5	5	4	8	12	100	87	94	90	80	85	0	13	7	10	20	15
10	3	3	6	0	1	1	92	92	92	100	97	99	4	4	4	0	3	2
11	0	1	1	1	0	1	100	97	99	95	97	96	0	3	2	5	3	4
12	4	4	8	1	3	4	90	90	90	97	92	95	6	6	6	4	-1	2
13	1	2	3	5	10	15	97	95	96	87	75	81	3	5	4	7	-5	1
14	0	4	4	1	2	3	100	90	95	97	95	96	0	10	5	-1	1	0
15	1	5	6	1	2	3	97	87	92	97	95	96	-1	9	4	-1	1	0

Group II

S*	RNC	RC	AV	LNC	LC	AV**	RNC	RC	AV	LNC	LC	AV	RNC	RC	AV	LNC	LC	AV
1	0	8	8	2	4	6	100	80	90	95	90	93	0	20	10	5	10	8
2	2	6	8	2	4	6	95	85	90	95	90	93	5	15	10	5	10	8
3	0	1	1	7	2	9	100	97	99	95	82	89	-6	-3	-4	12	-1	6
4	0	8	8	1	3	4	100	80	90	97	92	95	-2	18	9	3	8	6
5	1	0	1	0	1	1	100	97	99	100	97	99	0	3	2	0	3	2
6	7	8	15	6	2	8	82	80	81	95	85	90	18	20	19	5	15	10
7	0	0	0	1	1	2	100	100	100	97	97	97	0	0	0	1	1	1
8	4	3	7	6	6	12	90	92	91	85	85	85	10	8	9	13	13	13
9	2	1	3	0	2	2	95	97	96	96	97	97	5	3	4	0	5	3
10	4	4	8	0	3	3	90	90	90	100	92	96	10	10	10	0	8	4
11	0	3	3	1	2	3	100	92	96	97	90	94	0	8	4	3	10	7
12	4	8	12	11	21	32	90	80	85	72	47	60	-4	6	1	-4	21	9
13	6	13	19	3	7	10	85	67	76	92	82	87	15	33	24	2	8	5
14	8	12	20	3	9	12	80	70	75	92	77	84	16	26	21	-10	5	3
15	2	2	4	0	0	0	95	95	95	100	100	100	5	5	5	0	0	0

S* Subject; AV** Average total number of errors for a particular ear

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