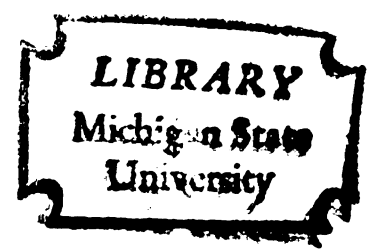


COMPARISON OF PURE-TONE
AND WARBLE-TONE THRESHOLDS

Thesis for the Degree of Ph. D.
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WAYNE JOSEPH STAAB
1971



This is to certify that the
thesis entitled

COMPARISON OF PURE-TONE AND WARBLE-TONE THRESHOLDS

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of the requirements for

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ABSTRACT

COMPARISON OF PURE-TONE AND WARBLE-TONE THRESHOLDS

By

Wayne Joseph Staab

Warble-tone stimulus parameters of frequency deviation and modulation rate were investigated to determine their effect on hearing threshold.

Three normal-hearing experienced listeners were presented with thirty randomized combinations and thirty repeated measures (for a total of sixty) warble-tone frequency deviations and modulation rates. Using a sinusoidal base frequency, thresholds were measured for the following frequency deviations: 1, 3, 6, 10, and 50%. The modulation rates investigated were: 1, 2, 4, 8, 16, and 32 per second. The thresholds obtained for each of six octave frequencies from 250 through 8000 Hz were then compared with the same subject's conventional, pure-tone air-conduction thresholds. Each subject's hearing threshold levels were measured monaurally on six separate occasions, with one frequency tested per session utilizing a 2 dB step descending method.

In general, substantial agreement was found between warble- and pure-tone thresholds. However, differences were found for some stimulus parameter conditions. These differences varied by test frequency and warble-tone combination (frequency deviation and modulation rate). The

results demonstrated that changes in frequency deviation had a greater influence on threshold than changes in modulation rate. This was particularly noticeable for the $\pm 50\%$ frequency deviation conditions. While threshold changes related to frequency deviation were not consistent across frequencies, lower modulation rates generally resulted in better thresholds for a given frequency deviation at all test frequencies.

Two "changeover" regions were observed with respect to the types of warble-tone patterns, one between 250 and 500 Hz and the other between 1000 and 2000 Hz. The direction of threshold response reversed in these regions and was most noticeable with wider frequency deviations, e.g., from $\pm 10\%$ to $\pm 50\%$. That is, warble-tone thresholds were better than pure-tone thresholds at 250 Hz, poorer at 500 and 1000 Hz, and were better again at 2000, 4000, and 8000 Hz.

Poorer thresholds generally were found with lower modulation indices (frequency deviation divided by modulation rate) for all frequencies and frequency deviations. In contrast to previous investigations, no evidence was found to support the notion that one or a combination of modulation indices provides a guideline for threshold prediction when testing normal hearing adult listeners.

Intersubject reliability of warble-tone thresholds was good ($p. \leq 0.05$). In addition, variability in warble-tone thresholds was small with the exception of 8000 Hz.

In general, warble-tone combinations up to and including frequency deviations of $\pm 10\%$ and modulation rates as fast as 32 per second resulted in close agreement (± 5 dB) between warble- and pure-tone thresholds for normal hearing adults.

**COMPARISON OF PURE-TONE
AND WARBLE-TONE THRESHOLDS**

By

Wayne Joseph Staab

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CHAPTER I

INTRODUCTION

Early identification and management of hearing loss is of paramount importance if a young child's speech and language are to develop adequately. Exact knowledge of the function of the auditory system is necessary for planning a training program for those with communicative disorders due to a hearing problem.

The neonatal auditory test procedures described by Wedenberg (1956), Hardy, Dougherty and Hardy (1959), Downs and Sterritt (1967), and Schulman and Fontana (1969), as well as many others have proven helpful in the early identification of deafness in infants. Likewise, screening tests described by Johnston (1948, 1952), Reger and Newby (1947), Gardner (1947), Meyerson (1956), Nielsen (1952), Webster (1952), Glorig (1953), Glorig and Wilke (1952) and others have provided useful information for an age range from childhood through adulthood. However, from the audiological and educational point of view, many methods used to test the hearing of young children (screening and/or threshold) do not provide sufficient information concerning the child's threshold sensitivity. In fact, the period from birth up to $2\frac{1}{2}$ or 3 years of age, before conditioned-play audiometry can be used (Barr, 1955; Hillis and Oyer, 1960), has remained baffling with regard to threshold audiometry. Attempts have been made to obtain behavioral responses with a variety of stimuli, including bells, the human voice, pure-tones, gongs, clackers,

oral instructions, household sounds, white noise, buzzers, etc. A difficulty with the presentations of the majority of these test stimuli is that the frequency and intensity characteristics are not consistent or controllable. In addition, it is important to have information about hearing threshold levels as a function of frequency. However, young children frequently refuse to wear earphones for pure-tone threshold measurements. To circumvent this problem, a number of individuals have suggested the use of pure-tones in a sound-field condition (DiCarlo and Bradley, 1961; Bender, 1967; and Smith, 1969). While testing in a sound-field cannot yield results as precise as those under earphones, this method can provide useful information about a child's hearing that often may not be obtained in any other way. However, if one introduces pure-tones into a sound-field, reflections from the boundaries of the test room may result in standing waves. As a result, some of the sounds will be reinforced and others cancelled as the subject shifts position within the room. The frequencies which are affected will depend upon the acoustical characteristics of the particular test room, and the reflections are a more serious problem in some rooms than in others. This problem can be resolved satisfactorily by the use of a frequency-modulated signal (warble-tone).

Since its introduction into hearing testing, the warble-tone stimulus has been advocated for clinical use as a method of threshold testing, especially for children (Reilly, 1958a, 1958b; Allison Laboratories, Inc., Bulletin A-5; Langenbeck, 1965; Miller and Polisar, 1964; Hardy, 1958; Heron and Jacobs, 1968, 1969; Miller and Rabinowitz, 1969; Liden Kankkunen, 1969; Peck, 1970). Likewise, some commercial neonatal testing devices employ a narrow band noise produced by frequency modulation

for infant hearing screening. Further, personal communication with a number of audiologists suggests that warble-tone is becoming a popular stimulus for threshold measurement.

Warble-Tone As An Auditory Stimulus

Warble-tone is produced by frequency modulation. Frequency modulation refers to a periodic modification of a base or center frequency, with a variation of this base frequency to values either above, below, or around it with amplitude held constant.

The warble-tone varies as a function of three basic parameters: (1) the center or base frequency, (2) the frequency deviation (FD), and (3) the modulation rate (MR). The center or base frequency is the frequency around which the modulation or frequency change takes place. The frequency deviation (range of percent of frequency change or actual variation in Hz of frequency change) is explained as follows: If the base frequency is 1000 Hz, then a plus and minus ($\pm$) 5% frequency deviation around the base frequency would produce a variation in the 1000 Hz tone from a low of 950 Hz to an upper frequency of 1050 Hz or a ± 50 Hz change. As this signal is repeated, the warbling sensation results. For a tone that warbles above the base frequency, the change for a plus (+) 5% range would be from 1000 Hz to 1050 Hz for a 1000 Hz base frequency or a +50 Hz change. Thus, a $\pm 5\%$ change is an actual nominal 10% frequency change, whereas a +5% is a nominal 5% change.

The modulation rate (rate of frequency change) refers to the number of times per second that the frequency varies (warbles) from one extreme to the other of the frequency limits. A modulation rate of 3 per second for a frequency deviation of +5% for a 1000 Hz base frequency would

mean that the tone would change in frequency from 1000 Hz to 1050 Hz three times a second.

Warble-tone is currently included as an accessory stimulus by some manufacturers of clinical audiometers. Although little has been written about the status of warble-tone in audiometers, Staab and Rintelmann (1971) conducted a survey among manufacturers in nine countries to ascertain the current status of warble-tone with respect to the various warble-tone characteristics available on commercial audiometers. Concerning the warble-tone signal itself, replies of respondents to the questionnaire indicated that the frequency deviation varied from approximately +0.2% above the base frequency to as high as $\pm 10\%$ around the base frequency. The modulation rates ranged from 2 per second to as high as 10 per second. Audiometer manufacturers accomplished the warble-tone in essentially two different ways, either by modulating around the base frequency or above the base frequency, with the waveform of the warbled signal either sinusoidal or rectangular. The signals were not calibrated to any single accepted, current standard. Of those manufacturers of audiometers who did not offer the warble-tone as a stimulus, their primary reason was that the warble-tone's significance had not been determined adequately and that there had been little or no demand for it as an auditory stimulus. Staab and Rintelmann (1971) concluded:

. . . there is a dearth of information concerning the most appropriate warble-tone stimulus parameters to be employed in threshold determination. This problem must be resolved before warble-tone audiometry can seriously be considered as part of the audiologist's clinical armamentarium (Unpublished).

In addition, no studies have systematically explored the comparison between warble-tone thresholds and thresholds obtained by conventional, pure-tone audiometry. Since the warble-tone stimulus characteristics

(frequency deviation, modulation rate, and waveform) are variable among commercial audiometers, differences in threshold might be expected simply as a function of the variety of stimulus parameters employed.

Statement of Purpose

From the review of literature it is obvious that information concerning the appropriate stimulus parameters with respect to the modulation rates and frequency deviations used for warble-tone audiometry is lacking. The specific questions which should be answered are:

1. How do warble-tone thresholds employing various combinations of modulation rates and frequency deviations compare with each other and with conventional pure-tone thresholds?
2. How do warble-tone thresholds (with respect to frequency deviation and modulation rate) vary as a function of frequency?
3. What is the interaction of frequency deviation with modulation rate?
4. What is the relation among the threshold rankings of the various warble-tone combinations by the subjects?
5. What are the effects of the modulation index (the ratio of frequency deviation to modulation rate) on warble-tone thresholds?

CHAPTER II

REVIEW OF THE LITERATURE

The following discussion presents a review of the literature relevant to this investigation. The review includes: (1) studies suggesting warble-tone for threshold determination, (2) literature concerned with comparisons (direct and/or indirect) of the warble-tone threshold and conventional pure-tone thresholds, and (3) investigations of warble-tone stimulus parameters that are currently being used on commercially-available audiometers.

Warble-Tone for Threshold Determination

The warble-tone stimulus is currently being used and has been evaluated by a number of individuals for neonatal hearing testing (Mendel, 1968; Beadle and Crowell, 1962; Heron and Jacobs, 1968, 1969; Peck, 1970). However, it must be realized that when used for neonatal testing, the response that one intends to obtain is that of a behavioral response to a suprathreshold stimulus and not a threshold level measurement. At least some of the "warble-tones" created by neonatal hearing testing devices give the subjective listening impression of being narrow bands of noise rather than that of a frequency modulating signal. This is due to the generation of the stimulus signal with frequency deviations around plus and minus ($\pm$) 150 Hz and modulation rates of 30 to 40 per second (Phonic Ear and the Rudmose RA-109 Warblet 3000). Stevens and

Davis (1938) have indicated that when the modulation rate increases to as high as 12 per second one begins to experience a group of tones rather than a single modulating tone. Because of this, and because of the fact that they are not intended for threshold determination (due to the high sound pressure level tones generated to elicit behavioral responses), no further mention will be made of the neonatal testing devices unless they have been advocated for threshold determination at some later developmental age of the infant.

As a measurement of behavioral response to warble-tone stimuli, Huising in 1953 (cited in Jerger, 1963) reported the moving of a block as the conditioned response with children between 30 months and 7 years of age. This sound-field conditioning procedure was used as an introductory test to threshold measurement (which involved pure-tones delivered through earphones).

Reilly (1958a) who was influenced by the work of Huising developed an instrument for sound-field testing of children. Based on Huising's apparatus, it used warble-tone for the clinical determination of threshold. This instrument, the "Audie-Frequency Wobbulator," allowed for output to two sets of speakers; one set portable and the other set fixed to the arms of a chair on which the subject was seated. Reilly suggested that testing with warble-tone could begin at 6 months of age but that the possibility at "play" audiometry occurred with the 21 to 33 month age group. Children 33 months and older were introduced to warble-tone while playing at a table, and, as their familiarity with the test signal increased were taken to the test chair. Audiograms were then obtained by means of play audiometric techniques using warble-tone introduced through the speakers at fixed distances from the child's head. Pure-tones

were later substituted for the warble-tone and audiograms again obtained. Finally, the child was introduced to the headphones. With the experiences the child has had from the sound-field testing conditions he will tolerate the earphones more easily and at a younger age. As a result, pure-tone audiograms can be recorded much earlier than usually is the case. Reilly commented that the youngest child from whom he had been able to obtain a warble-tone audiogram was just under 2 years of age.

Again, in a panel discussion on "The Assessment of Auditory Function: I. Hearing in Children," Reilly (1958b) stated that he had been using frequency modulation in testing babies and young children, and that during a six month period had good success with this method. He wondered why this had not been discussed by the panel when speaking about successful techniques used with children. In response Hardy (1958) commented that they had used frequency modulation for six or seven years as part of the pure-tone battery in testing. He felt that it was a good attention centering device and that responses were sometimes obtained that could not ordinarily be elicited, especially with children having nervous system involvement.

Miller and Polisar (1964) in a textbook concerning the audiological evaluation of the pediatric patient, wrote that . . . "Frequency modulation is an effective way of breaking up standing wave patterns and should be utilized whenever pure tone testing is performed in a sound field" (p. 30). They stated that both sound-field pure-tone threshold measurements and sound-field hearing aid evaluations could be better accomplished with the use of warble-tone.

In still another textbook, Langenbeck (1965) stated that if the audiometer has a provision for the continuous alteration of frequency

with intensity maintained constant, that it should be utilized to help determine the threshold curve. He further wrote that with respect to children, especially those from about 5 to 7 years of age, the tester can be just as successful as he is with adults if he can make "the game" a little more interesting for the child. One technique that can be used is to move the frequency dial up and down, which results in "webbling" of tones with changes in pitch. This adds a somewhat fluid character to the audiometric signal which maintains the child's attention.

By contrast, it should be noted that none of the three most commonly-used textbooks for the introductory study to audiology in the United States have a single reference to the assessment of hearing thresholds in children with a warble-tone stimulus (Newby, 1964; O'Neill and Oyer, 1966; Davis and Silverman, 1970).

Miller and Rabinowitz (1969) performed COR (Conditioned orienting reflex audiometry) on 183 children as part of a complete audiological evaluation. The stimuli used were pure-tones in the 250-4000 Hz range frequency-modulated by 5% of the basic frequency. The children tested were in two subgroups of a rubella population; those with hearing impairments only, and those with hearing impairment plus one or more associated problems. The technique was successful with 76 of the 183 children tested. They reported: "COR and sound field audiometry are used only on children who cannot respond to conventional audiometric testing with earphones and a bone conduction vibrator" (p. 95).

Liden and Kankkunen (1969) reported on a visual reinforcement audiometric technique in the testing of young deaf children which utilized the warble-tone. The apparatus was primarily designed for measuring the monaural sound-field thresholds for warble-tones. For

visual reinforcement they used slides projected on a frosted glass window located on each side of a curved front panel of a box-shaped apparatus. They began with a 500 Hz warble-tone presented to the right loudspeaker at 30-40 dB above the estimated threshold, and immediately followed this with a picture on the right window. The visual reinforcement was intended to make the rather meaningless pure-tones more interesting to the children. By gradually reducing the intensity and watching the response of the child, it was possible to obtain a pure-tone threshold.

By the mid 1950's manufacturers of audiometers began to advocate the use of warble-tone for threshold determination and other purposes. Allison Laboratories, Inc. Bulletin A-5 (not dated) sent a questionnaire on "The Use of Warble Tone" to a group of users (number in group not indicated) of their equipment which had the warble-tone feature available. Of those that replied, more than 85% indicated that the warble-tone was used for threshold measurement either through the earphones or loudspeaker. Allison Laboratories reported surprise in the large percentage using warble-tone for threshold measurements. More specifically, advantages were given by respondents for warble-tone with children, the elderly, and for those with tinnitus. Other uses of the warble-tone included in the questionnaire responses were: masking for pure-tones, measurements through the loudspeaker of hearing aid frequency response, measurements through the loudspeaker of hearing aid gain, and difference limen frequency tests.

In a 1964 manual on operating instructions for their warble-tone adapter, the Beltone Electronics Corporation suggested the use of warble-tone in cases of tinnitus, sound-field pure-tone testing, and

for frequency difference limen. Carver (1965) in a booklet entitled Major Audiometric Measurements As Performed With Beltone Audiometric Instrumentation, also suggested that warble-tone be used for cases with tinnitus. However, he did not discuss its use for frequency difference limen. He did add that the warble-tone in a sound-field allows for aided and unaided threshold measurements and was advantageous when measuring thresholds of children because it holds their attention longer than pure-tones.

Madsen Electronics' operating manual for their clinical audiometer (Model OB 60) with the warble-tone stimulus makes no mention of the warble-tone being used for threshold measurement. Instead, they recommend its use for a difference limen for frequency (DLF) test.

Tracor, manufacturer of the Allison Model 22 Clinical and Research Audiometer, states that the warble-tone is an excellent stimulus for use where tinnitus is present. It also serves as an effective masking signal for pure-tones and as a sound-field signal for those who cannot be tested with earphones (Tracor Specification Sheet for the Allison Model 22 Audiometer).

In correspondence with the Rion Company of Japan, manufacturers of audiometers, the following statement was made with respect to the warble-tone stimulus: "This can be used to decide threshold value for kindergarten children within a short time. It can be applied for mentally retarded persons also" (personal correspondence, 1970).

In a questionnaire survey by Staab and Rintelmann (1971) to manufacturers of audiometers in nine countries, of those who included warble-tone as an auditory stimulus, the most often suggested use was for threshold measurement in sound-field or under earphones. However,

only two of six manufacturers reported that they had published instructions on its use for threshold measurement.

Comparison of Warble-Tone and Conventional Pure-Tone Thresholds

The literature review included in this section is taken from studies indirectly rather than directly related to these two types of stimulus thresholds. No study has been located in the literature which has systematically made this comparison.

In 1933, Sivian and White utilized the warble-tone with the psychophysical method of limits to determine the upper portion of the monaural, minimal audible field (MAF) thresholds for 0° incidence on 14 "normal" listeners (Sivian and White, 1933). The reasons given for using the warble-tone were ". . . psychological, in that it reduces fatigue and uncertainty on the part of the observer; and physical, because of smoothing out of the residual standing wave patterns produced by reflections" (p. 290). They used a constant modulation rate of 10 per second and a frequency deviation which was progressively reduced in percent from approximately $\pm 4.6\%$ at 1100 Hz (± 50 Hz) to approximately $\pm 0.97\%$ at 15,000 Hz (± 146 Hz). They reported that a few check measurements made on the same individual with the warble- and pure-tone indicated no systematic differences between the threshold values in the two stimulus situations other than those due to the physical and psychological considerations the warble-tone was intended to minimize. Binaural MAF threshold measurements performed the same way and also done without a "warble" tone resulted in similar results to those in the monaural MAF condition. These measurements were all made at a distance of one meter in front of a loudspeaker in a highly absorbing acoustic structure which they called the "sound stage."

Webster (1952) reported on a recorded, pulsed-tone group hearing test which used warble-tones with a modulation rate of 5 per second and an unspecified frequency deviation. The test was given to 200 college students in both a sound-field condition in a reverberant room and under earphones. When compared with two other control group hearing tests [one consisting of recorded warble-tones through headsets and the other a pure-tone pulse test described by Meyers et al., (1948)], this test was as reliable as the better of the two control tests whether heard over earphones or loudspeakers. He concluded that as a screening device this test was satisfactory. Webster also indicated that "Enough information is available so that the headset levels could have been pre-set to read directly in 'hearing loss' values" (p. 217).

More recently, Reilly (1958a) used an instrument for sound-field testing of children called an Audio-Frequency Webbulator based on one used by Huizing in The Netherlands for the clinical determination of threshold by warble-tone. Both the modulation rate and the frequency deviation were variable, the former unspecified and the latter from ± 0 to ± 100 Hz. He also mentioned (but presented no data), that:

By using pure-tone sounds in the speakers instead of the warbling tone it is easily demonstrated that a child will respond to a warbling tone of much less intensity than to a pure-tone of the same frequency (1958a, p. 365).

In two recent articles (Dallos and Tillman, 1966; Young and Harbert, 1970) some effects of the modulation index (the ratio of frequency deviation to modulation rate) was sampled by Bakesy tracings but not systematically explored. Both studies specifically looked at threshold changes in abnormally adapting ears but also included some limited data concerning normal listeners.

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Dallos and Tillman (1966) used four different modulation rates (1, 2.5, 10, and 25 per second) and three different frequency deviations (10, 63, and 250 Hz which were ± 1 , approximately ± 6 , and $\pm 25\%$ respectively) at 500 Hz with one normal hearing subject (one ear). The results showed that in general, the hearing sensitivity threshold improved slightly with increasing frequency deviation, and that consistently better thresholds were obtained with slower repetition rates. They suggested, however, that it is the modulation index (ratio of frequency deviation to modulation rate) which might be the critical variable in determining threshold sensitivity, and that under this condition better thresholds are obtained with smaller frequency deviation.

Young and Harbert (1970) utilized four normal, trained listeners (four ears) and modulation rates of 1, 4, 10, and 25 per second and frequency deviations of ± 10 , ± 63 , and ± 250 Hz. Threshold values obtained by fixed frequency Békésy audiometry at 1000 Hz showed that the thresholds remained about the same or improved slightly with increasing frequency deviation. As the modulation increased for a given frequency deviation, the threshold became poorer. The greatest dB change between the combinations of frequency deviation and modulation rate was 7.1 dB. With respect to the modulation index, however, Young and Harbert tend to confirm Dallos and Tillman's observation that better thresholds are obtained with smaller frequency deviation.

In an investigation of warble-tones with very young children, Peck (1970) used a frequency deviation of 5% to determine auditory thresholds. He reported that it was difficult to give a precise reference level for the warbled sound-field pure-tones, but that the results were assumed

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to approach the ISO-1964 zero reference levels. He did not specify the modulation rate used.

While not related specifically to threshold, in a study of respiratory curve responses of the neonate to auditory stimulation, Heron and Jacobs (1968) found that of a variety of test tones, warble-tone produced the most consistent response. In 1969 they had a warble-tone audiometer built to their specifications which had three frequency ranges: 250-500, 1000-2000, and 4000-8000 Hz. In each of these ranges it was possible to modulate the frequency up to $\pm 1/3$ of the center frequency. The modulation rate could be altered from 1 to 10 per second in gated steps. After many trials they found that the following settings were the most effective:

1. Low frequency. Full modulation for 4 seconds at a modulation rate of 10 per second.
2. Middle frequency range. Full modulation for 4 seconds with a modulation rate of 6 per second.
3. High frequency range. Full modulation for 4 seconds with a modulation rate of 4 per second.

It is obvious from the aforementioned studies that none were designed to systematically investigate the threshold levels obtained for different center frequencies with varying combinations of modulation rates and frequency deviations. Still, the results of Dallos and Tillman (1966) and Young and Harbert (1970) suggest that the warble-tone stimulus parameters (pertaining to modulation rate and frequency deviation) do have an effect on hearing threshold levels.

Warble-Tone Stimulus Parameters Currently Used

There is a dearth of published information concerning the warble-tone stimulus parameters currently being used. Because they suspected that the stimulus parameters varied considerably by manufacturer, Staab and Rintelmann (1971) conducted a survey to determine the current status of warble-tone in audiometers. Of twenty-nine audiometer manufacturers, twenty-four replied (82.7%), representing nine different countries. Nine manufacturers indicated that they already employ or are planning to include warble-tone on their audiometers in the near future. Of eight manufacturers (33.3%) that provided information relative to the stimulus parameters, the following information was obtained: (1) frequency deviation varied from approximately +0.2% above the base frequency to as high as $\pm 10\%$ around the base frequency, (2) modulation rate ranged from 2 per second to as high as 10 per second, (3) audiometer manufacturers accomplished the warble-tone in essentially two different ways: either by modulating around the base frequency or above the base frequency, (4) the waveform of the warbled signal was either sinusoidal or rectangular, and (5) the signal was not calibrated to any single accepted, current standard. With respect to the frequency deviation and the modulation rate, the consensus of the respondents was that the bases for the parameters currently being used had not been adequately substantiated by published research.

Aside from the study just cited, no information has been located which directs attention to the stimulus parameters being used in commercial audiometers.

Summary

While some individuals have advocated the use of the warble-tone stimulus for threshold determination, especially for young children, little information is available relative to the appropriate stimulus parameters. Systematic investigation of various frequency deviation and modulation rate combinations should be performed to determine which combination(s) give threshold levels that most closely approximate those obtained by conventional pure-tone audiometry. Although one of the major applications of warble-tone audiometry is intended for testing young children, a careful study of the important stimulus parameters should first be accomplished with experienced adult normal listeners. It is the purpose of this study to obtain such data. Thereafter, in order to obtain normative data which can be applied clinically, subsequent studies can be conducted on a limited number of stimulus parameter combinations on a large sample of children and adults. After such investigations have been completed, warble-tone audiometry can be meaningfully employed as part of the audiologist's clinical armamentarium.

CHAPTER III

EXPERIMENTAL PROCEDURES

Information concerning the selection of subjects, instrumentation, ambient noise levels, calibration, stimuli employed, and the experimental procedures utilized are included in this chapter. Briefly, three normal-hearing experienced listeners were individually administered thirty combinations (sixty repeated measurements) of frequency deviations and modulation rates for each of six frequencies at octave intervals from 250 through 8000 Hz. The warble-tone thresholds obtained were then compared with the same subject's conventional, pure-tone air-conduction thresholds at the same test frequencies and for the same ear.

Subjects

Three normal-hearing adult females, ages 22, 25, and 30 served as participants in the study. Since the study was primarily designed to compare each individual's conventional, pure-tone air-conduction thresholds with his warble-tone thresholds, three subjects were considered to be adequate. The subjects were selected on the basis of the following criteria:

1. No previous history of ear pathology.
2. No constant or disturbing tinnitus.
3. No family history of hearing impairment due to possible hereditary causes.

4. Hearing at least at 15 dB re ANSI-1969¹ reference thresholds for octave frequencies from 250 Hz through 8000 Hz in the test ear and with no air-bone gap.
5. Must have undergone at least ten pure-tone air-conduction threshold audiograms (criterion for experienced listeners).

Instrumentation

All equipment employed during testing, with the exception of the earphones, subject response button, bone vibrator, and calibration equipment was located in the control room of the test suite used in this study. The equipment mentioned (except the instruments necessary for air- and bone-conduction calibration) was located in the adjoining subject test room. Figure 1 provides a schematic diagram of the equipment used during testing.

Mico MA-24 Audiometer. The Mico Model MA-24 audiometer is a dual-channel instrument which allows for testing 11 frequencies from 125 through 8000 Hz and also has a Hearing Threshold Level range of from -25 dB to 110 dB re ANSI-1969. This audiometer was utilized in obtaining the pure-tone air-conduction, bone-conduction, and warble-tone threshold measurements in 2 dB steps of attenuation.

Oscilloscope and Spectrum Analyzer. The Type 564B Tektronix Storage Oscilloscope with Auto Erase is designed to store cathode-ray tube displays for viewing or photographing up to an hour after application of the input signal. In addition, the instrument can be operated as a

¹American National Standards Institute (ANSI) "Specifications for Audiometers" S3.6-1969.

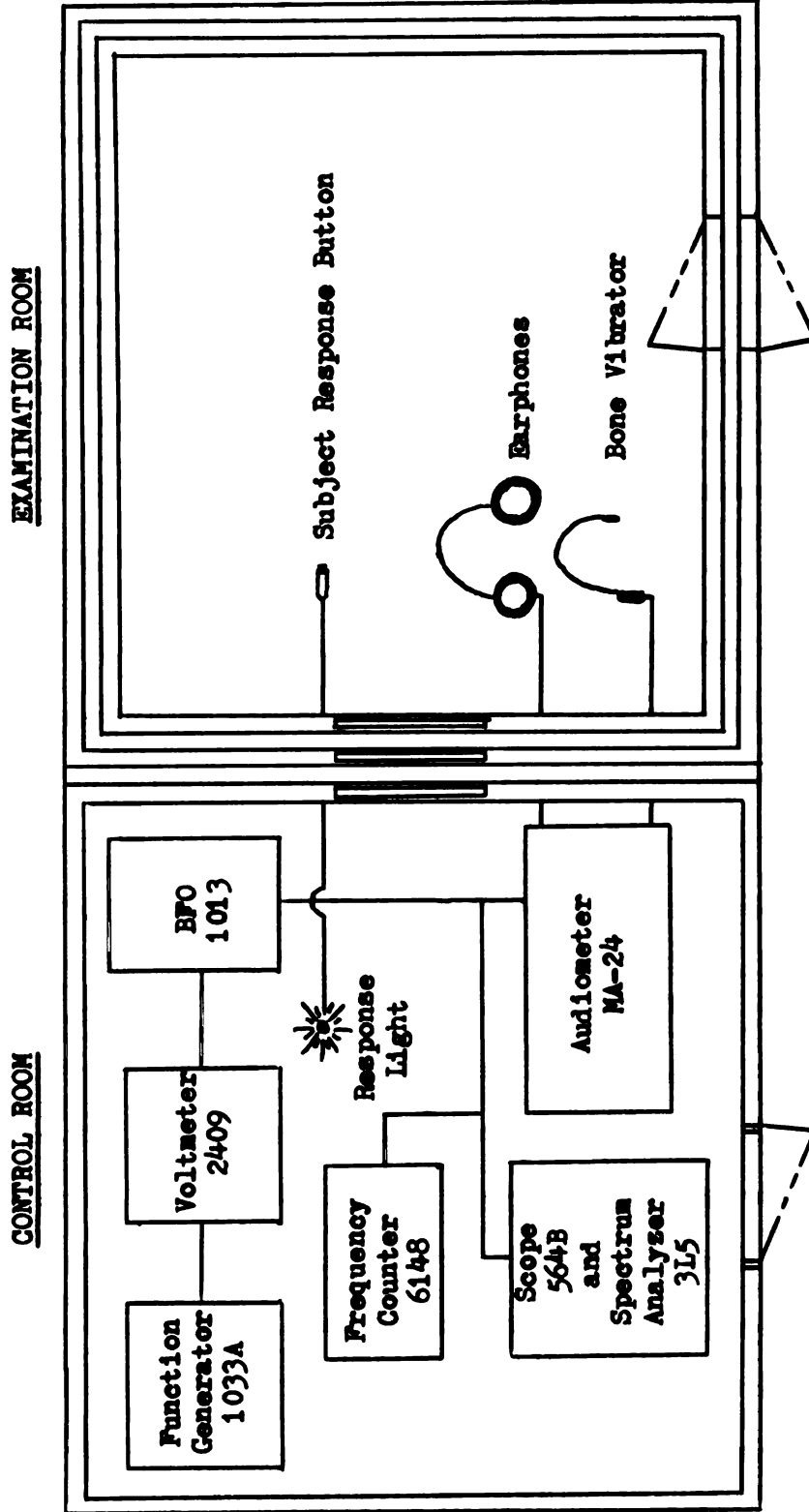


Figure 1. Block diagram of test environment showing equipment used.

conventional oscilloscope and was used this way to measure the stimuli rise and decay times. The oscilloscope is compatible with Tektronix plug-in units and a Spectrum Analyzer Model 3L5 was utilized to measure the warble-tone frequency deviations desired.

Function Generator. The Hewlett-Packard Model 3310A Function Generator is a voltage-controlled generator which allows for low distortion and high stability sine wave generation over a frequency range of 0.0005 Hz to 5 MHz in 10 decade ranges. The frequency of the sine wave generation determined the modulation rates and its output voltage was instrumental in obtaining the desired frequency deviation.

Voltmeter. A Bruel & Kjaer Type 2409 Electronic Voltmeter allowed for fine adjustments of the output voltage of the function generator. This voltmeter is a vacuum tube voltmeter for AC measurements in the frequency range from 2 Hz to 200,000 Hz. Eleven voltage ranges are present allowing for full-scale deflection from 10 millivolts to 1000 volts.

Frequency Counter. The Bekman Eput and Timer, Model 6148 is a 100 MHz unit which can measure frequency, time interval, period, multiple period, ratio, multiple ratio, and which counts random events. It has a stability of better than ± 3 parts in 10^9 per day. Visual measurements are presented in an eight-digit, inline, numerical display utilizing glow tubes. The display includes an automatically-positioned decimal point and an indication of units of measurement. This was used initially to determine the accuracy of the frequency of the modulation rates and then during the experiment to monitor the base or center frequencies of the test stimuli.

Beat-Frequency Oscillator. A Bruel and Kjaer (B&K) Beat-Frequency Oscillator Model 1013 was used as the main source for the generation of the warble-tones. This is designed for measurements in the frequency range 200-200,000 Hz and consists of an oscillator, mixer, and an amplifier section. It works on the heterodyne principle using two high-frequency oscillators, one of which operates on a fixed frequency, while the frequency of the other can be varied by means of a variable capacitor. The required signal base frequency is obtained as the difference between the two high frequencies and can be read off a large illuminated scale, the pointer of which is connected to the variable capacitor. The oscillator also allows for frequency modulation of the output signal.

Figure 2 shows a block diagram of the oscillator and the sections utilized in the generation and control of the warble-tone. The fixed oscillator is tuned to 1.2 MHz and can be externally frequency modulated by means of a REMOTE CONTROL² and reactance tube circuit. The latter acts as a variable inductance and the modulation swing (frequency deviation which is controlled by the amplitude of the oscillations) for this experiment was continuously varied from 0 to ± 4000 Hz. This was accomplished by means of a potentiometer on the front panel of the apparatus marked FREQUENCY DEVIATION and also by the output voltage of the external function generator. A variable capacitor inserted in the tuned circuit of the fixed oscillator and operated by the knob marked FREQUENCY INCREMENT, permits exact frequency selection in the range

²Words in capital letters in this thesis relate to controls (dials) on the equipment utilized in the experiment.

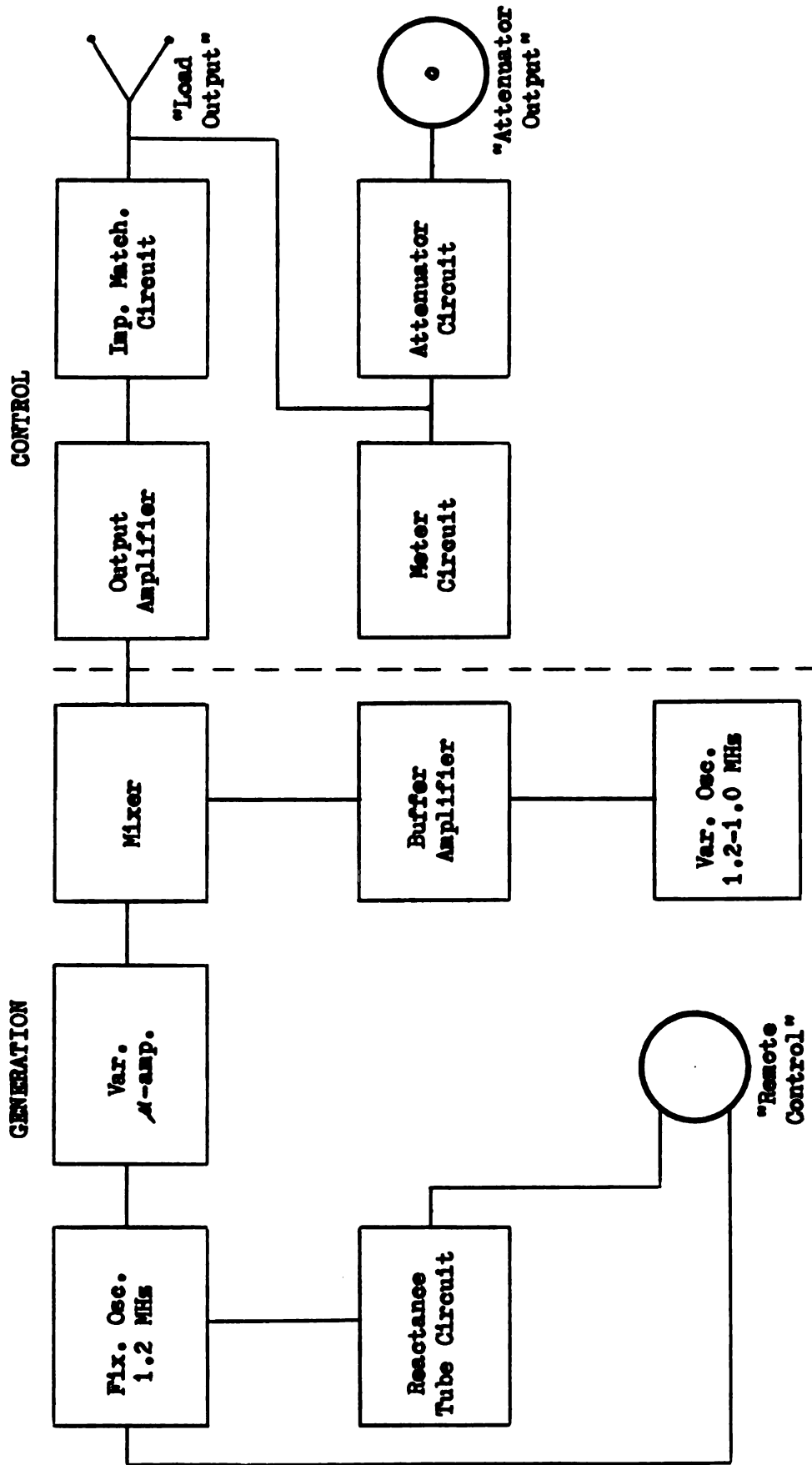


Figure 2. Block diagram of the beat-frequency oscillator (Brüel & Kjaer, Model 1013) with emphasis on its sections utilized in the generation and control of the warble-tone.

± 500 Hz in relation to the setting on the main scale. The frequency accuracy of the incremental scale is ± 5 Hz and that for the main scale is $1\% \pm 10$ Hz.

For external frequency modulation, an external generator (Hewlett-Packard Model 3310A Function Generator) was used to allow for sinusoidal frequency deviation changes, to allow for some variation of the range of frequency deviations, and to obtain modulation rates not allowed directly by the beat-frequency oscillator. This function generator was connected to two terminals of the jack of the front plate marked REMOTE CONTROL. For external modulation it was necessary to connect the external generator between terminals f and b of the REMOTE CONTROL and have the MODULATION FREQUENCY switch set to "Ext. Mod." The impedance of the external generator had to be low (approximately 1 kohm).

The voltage developed across the grid circuit of the variable oscillator is fed to the mixer tube via a buffer amplifier stage. This stage, which prevents undesired coupling between the fixed and variable oscillator, also increases the signal level to a value required for correct functioning of the mixer.

The LOAD was connected to the INPUT of the storage oscilloscope and related spectrum analyzer for measurement of the frequency deviation in Hz and also to the AC INPUT of the counter to monitor the warble-tone's base frequency.

The MATCHING IMPEDANCE of the beat-frequency oscillator was turned to "Attenuator" and the ATTENUATOR OUTPUT was set to 400 millivolts and led to the Maico MA-24 audiometer through its ACCESSORY INPUT. (This voltage was adequate to develop enough output at the earphones to allow for a "0" VU reading at all test frequencies.)

Test Environment

Subjects were tested in an Industrial Acoustics Corporation (IAC) Series 1600-ACT sound-treated room combination consisting of a 400 Series control room and a 1200 Series test booth. All threshold testing was presented monaurally via the right earphone (Telephonics TDH-39/10Z) mounted in a MX-41/AR cushion. The nontest ear was covered by the left earphone as would occur in normal testing conditions. The subject was seated alone in the test room and the majority of the equipment (except earphones, bone vibrator, and response button) was located in an adjacent control room.

Ambient Noise Levels in Test Room

The ambient noise levels of the test room were measured in accordance with the criteria set forth by the American Standards Association for "Background Noise in Audiometer Rooms" (ASA S3.1-1969).³ The levels measured and the instrumentation involved in making these determinations are recorded in Appendix A. The levels recorded met the criteria set forth by the ASA and, thus, were sufficiently low so as not to interfere with threshold measurements.

Calibration

Calibration of all test equipment took place at the beginning and at the end of the experiment. Specifically, the Maico MA-24 audiometer was calibrated and/or checked for frequency at octave intervals from

³While the name of the American Standards Association (ASA) is now the American National Standards Institute (ANSI), standards adopted prior to 1969 and the name change will be specified in this paper according to their original description.

250 through 8000 Hz, linearity of attenuation, sound pressure level (SPL) output, harmonic distortion, measurement of the rise and decay times of the stimulus, and bone-conduction. The instrumentation utilized in the generation and measurement of warble-tone (the beat-frequency oscillator and spectrum analyzer) was also calibrated according to the procedures specified in their respective operating manuals. Measurements of the signal to be warbled, including its base frequency, SPL output, and harmonic distortion were also measured at the earphone after it had been routed through the ACCESSORY INPUT of the Maico MA-24 audiometer.

In addition to the above, daily calibration checks were made of the SPL outputs and test frequencies. Calibration for the pure-tone stimuli was consistent with the American National Standards Institute (ANSI) 1969 "Specifications for Audiometers" and also the Hearing Aid Industry Conference (HAIC) "Interim Bone-Conduction Thresholds for Audiometry" (Lybarger, 1966). Calibration of the warble-tone stimuli followed the rationale and method given in Appendix B.

The instrumentation and procedures involved in the calibration checks and the results of those measurements are recorded in Appendices C through H.

Stimuli Employed

Stimuli employed during the experiment consisted of pure-tone air- and bone-conduction and warble-tone signals. For the warble-tone stimuli, the base frequency (a pure-tone) was frequency modulated so that frequency deviations occurred in a sinusoidal manner both above and below the base frequency.

Experimental Procedures

Each subject's hearing threshold levels were measured monaurally on six separate occasions for a total of fifteen hours per subject. This averaged $2\frac{1}{2}$ hours per session and followed the outline for each session as listed below.

Session #1.

- A. Monaural pure-tone air- and bone-conduction thresholds at six test frequencies (250, 500, 1000, 2000, 4000 and 8000 Hz).
- B. Five monaural pure-tone air-conduction thresholds at 1000 Hz.
- C. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 1000 Hz.

Session #2.

- A. Five monaural pure-tone air-conduction thresholds at 2000 Hz.
- B. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 2000 Hz.

Session #3.

- A. Five monaural pure-tone air-conduction thresholds at 4000 Hz.
- B. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 4000 Hz.

Session #4.

- A. Five monaural pure-tone air-conduction thresholds at 8000 Hz.
- B. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 8000 Hz.

Session #5.

- A. Five monaural pure-tone air-conduction thresholds at 500 Hz.
- B. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 500 Hz.

Session #6.

- A. Five monaural pure-tone air-conduction thresholds at 250 Hz.
- B. Thirty combinations (sixty repeated measures) of monaural warble-tone thresholds having a center frequency of 250 Hz.

Threshold Determination. Threshold determination (with the exception of the initial screening testing) for both the pure-tone and warble-tone signals was obtained by an orienting method of limits followed by a descending method utilizing 2 dB intensity increments. The specific instructions and procedures employed were as follows:

1. Instructions. The subject was instructed as follows:

You are to listen very carefully during this test. You will hear a series of sounds, some high-pitched and some low-pitched. (For the warble-tone thresholds the subject was also told that some of the tones will seem to warble and others will seem to be steady.) You are to respond by pressing the button I've given to you whenever you hear a sound and release it when the sound disappears. It is important that you listen and respond to very faint sounds, not merely when you can hear them easily. Do you have any questions?

2. Threshold. The specific procedure utilized in threshold determination was as follows:

- a. The auditory stimuli were initially arbitrarily presented at a 30 dB Hearing Level (HL).
- b. The intensity was then decreased in 10 dB steps with two presentations per level until no response was obtained on both presentations.
- c. The intensity was then increased by 10 dB and descents in 2 dB steps occurred with two stimulus presentations per level to establish a level where the subject correctly responded to 5 of 6 stimulus presentations.

- d. The intensity continued to decrease in 2 dB steps until the subject missed 5 of 6.
- e. Threshold was that value where the subject last correctly responded to both stimuli at a level minus 1 dB for each correct response below that point.
- f. As soon as threshold was obtained, the subject was told to relax.

Pure-Tone Threshold Tests. Monaural, pure-tone air-conduction thresholds were obtained at octave intervals from 250 through 8000 Hz during the first test session in ascending 5 dB steps (Carhart and Jerger, 1959). The purpose of these measurements was to insure that the subject met the criterion for acceptable hearing levels for the experiment. Frequencies were tested in the following order: 1000, 2000, 4000, 8000, 1000, 500, and 250 Hz. The repeat measurement obtained at 1000 Hz served as a reliability check. If the subject's threshold at 1000 Hz was not within ± 5 dB of the initial threshold at 1000 Hz, the subject was reinstructed and testing was again started at 1000 Hz.

Monaural, pure-tone bone-conduction thresholds were established at octave intervals from 250 through 4000 Hz during the first test session only by the Hood Technique (1960) employing narrow band masking provided by the Maico MA-24 audiometer. These were also obtained in 5 dB steps. Frequencies were tested in the following order: 1000, 2000, 4000, 1000, 500, and 250 Hz. The repeat measurement at 1000 Hz followed the same rationale as for air-conduction testing. The purpose of testing bone-conduction was to establish the subject's ability to meet the requirements specified for normal listeners--no air-bone gap.

After the criteria for normal hearing had been established, five pure-tone air-conduction thresholds were obtained for the frequency being tested utilizing the descending threshold procedure in 2 dB steps as previously described. These were obtained at specified times during the experiment with a single threshold measurement taken prior to the first warble-tone combination, and after the fifteenth, thirtieth, forty-fifth, and last warble-tone combinations. These were then averaged and represented the pure-tone thresholds with which the warble-tone thresholds were compared.

Warble-Tone Threshold Tests. Monaural warble-tone thresholds were obtained in 2 dB steps with center frequencies of 250, 500, 1000, 2000, 4000, and 8000 Hz utilizing thirty combinations for a total of sixty repeated measures of frequency deviations and modulation rates. The specific combinations used were derived from pilot data on two listeners who met the same requirements for normal hearing as did the test subjects. The ear tested was the right each for each subject. The order in which each subject was given a specific combination of frequency deviation and modulation rate was randomized so as to minimize temporal effects on thresholds. Table 1 shows the thirty combinations for a total of sixty repeated measures of modulation rates and frequency deviations used in this study for a single test frequency. The same combinations were available for each of the warble-tone center test frequencies. Appendix I shows the randomizations of combinations of frequency deviations and modulation rates for each subject per test session. The repeated measurements were obtained during the same test session. In Table 1 the legend in each cell, i.e., $(C_1, 1)$ denotes the combination (C) of frequency deviation

Table 1. Combinations (C) of frequency deviations (1st subscript) and modulation rates (2nd subscript) utilized to produce the warble-tone at each test frequency. The table shows that repeated measurements were obtained.

		Frequency Deviation in Percent				
Modulation Rate		$\pm 1.0\%$	$\pm 3.0\%$	$\pm 6.0\%$	$\pm 10.0\%$	$\pm 50.0\%$
1/sec.	Measure 1	C _{1,1}	C _{3,1}	C _{6,1}	C _{10,1}	C _{50,1}
	Measure 2	C _{1,1}	C _{3,1}	C _{6,1}	C _{10,1}	C _{50,1}
2/sec.	Measure 1	C _{1,2}	C _{3,2}	C _{6,2}	C _{10,2}	C _{50,2}
	Measure 2	C _{1,2}	C _{3,2}	C _{6,2}	C _{10,2}	C _{50,2}
4/sec.	Measure 1	C _{1,4}	C _{3,4}	C _{6,4}	C _{10,4}	C _{50,4}
	Measure 2	C _{1,4}	C _{3,4}	C _{6,4}	C _{10,4}	C _{50,4}
8/sec.	Measure 1	C _{1,8}	C _{3,8}	C _{6,8}	C _{10,8}	C _{50,8}
	Measure 2	C _{1,8}	C _{3,8}	C _{6,8}	C _{10,8}	C _{50,8}
16/sec.	Measure 1	C _{1,16}	C _{3,16}	C _{6,16}	C _{10,16}	C _{50,16}
	Measure 2	C _{1,16}	C _{3,16}	C _{6,16}	C _{10,16}	C _{50,16}
32/sec.	Measure 1	C _{1,32}	C _{3,32}	C _{6,32}	C _{10,32}	C _{50,32}
	Measure 2	C _{1,32}	C _{3,32}	C _{6,32}	C _{10,32}	C _{50,32}

and modulation rate utilized. The first subscript denotes the frequency deviation in percent and the subscript following the comma denotes the modulation rate. In Appendix J the specific frequency deviations for each test frequency are given in both percent and Hz along with the modulation rates. Also included is information on the FREQUENCY DEVIATION position of the beat-frequency oscillator, the VOLT SCALE and output voltage of the function generator and the Hz/DIV scale on the storage oscilloscope required to produce and measure the warble-tone stimuli.

In obtaining warble-tone thresholds for each subject in each test session the following procedure was followed:

1. Preliminary Procedure for Warble-Tone Thresholds.

- a. The center frequency of the warble-tone was selected by varying the main frequency dial of the beat-frequency oscillator and it was monitored with the frequency counter until the desired center or base frequency was obtained.
- b. With the modulation rate set at 4 per second, the VU meter of the Maico MA-24 audiometer was adjusted to give a "0" VU reading through the ACCESSORY INPUT.

2. Test Procedure for each Warble-Tone Threshold.

- a. Appendix I was consulted to determine the combination of frequency deviation and modulation rate to be used for each threshold determination.
- b. With the knob marked MODULATION FREQUENCY of the beat-frequency oscillator turned to "Ext." and the knob marked FREQUENCY DEVIATION to the frequency deviation required, the external function generator was varied in:

- 1) its output frequency to obtain the desired modulation rate,
and
- 2) its output voltage to establish the frequency deviation
desired.

(The relationship of the output voltage of the function generator to the FREQUENCY DEVIATION setting required for a specific range of warble-tone in Hz had previously been systematically explored with a storage oscilloscope and associated spectrum analyzer. Appendix J gives the output voltages required along with the beat-frequency oscillator FREQUENCY DEVIATION setting needed to obtain the desired frequency deviation for each warble-tone combination.)

- c. The center or base frequency was readjusted with the FINE FREQUENCY SCALE ALIGNMENT of the beat-frequency oscillator.⁴
- d. The descending warble-tone threshold was obtained following the procedures previously outlined.
- e. Steps "a" through "d" were repeated for each warble-tone threshold combination for all subjects during each test session.

⁴Even though a single base or center frequency was utilized for the warble-tone combinations on a given day, changes in the FREQUENCY DEVIATION setting of the beat-frequency oscillator resulted in shifts of the center frequency. To compensate for these shifts, the FINE FREQUENCY SCALE ALIGNMENT of the beat-frequency oscillator was adjusted until the desired center frequency was again obtained.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the results of the pure-tone and warble-tone threshold measurements along with the presentation of the findings relative to the questions proposed. This is followed by a discussion and a summary.

Pure-Tone Threshold Results

The criterion for "normal" hearing specified that thresholds should be at least 15 dB re ANSI-1969 reference levels for octave frequencies from 250 through 8000 Hz in the test ear and with no air-bone gap. The initial screening was performed using ascending 5 dB steps according to the method advocated by Carhart and Jerger (1959). For the experiment, descending pure-tone air-conduction thresholds were obtained prior to the first warble-tone combination and after the fifteenth, thirtieth, forty-fifth, and last warble-tone combinations. Table 2 presents each subject's right ear pure-tone air-conduction descending thresholds along with the mean threshold in Hearing Threshold Level (HTL) and Sound Pressure Level (SPL). Multiple measurements of the air-conduction thresholds were obtained to allow for better averaging of threshold since preliminary testing indicated that they were not as consistent as warble-tone thresholds. Figure 3 displays graphically the Hearing Threshold Levels according to the ANSI-1969 Standard.

Table 2. Monaural, descending pure-tone air-conduction thresholds obtained during each test session for each subject at six frequencies along with the mean HTL (ANSI-1969) and SPL threshold values.

Subject	Frequency in Hz	Test 1	Test 2	Test 3	Test 4	Test 5	Mean	
							HTL	SPL*
#1	250	-3.0	-8.0	4.0	-2.0	-8.0	-3.4	22.0
	500	-3.0	-5.0	-3.0	-6.0	-6.0	-4.6	7.0
	1000	-9.0	-5.0	0.0	-8.0	-3.0	-5.0	2.0
	2000	-5.0	0.0	-3.0	3.0	-6.0	-2.2	6.8
	4000	14.0	5.0	17.0	14.0	11.0	12.2	21.7
	8000	11.0	10.0	13.0	12.0	14.0	12.0	25.0
#2	250	4.0	2.0	-2.0	1.0	2.0	1.4	26.8
	500	0.0	0.0	-4.0	2.0	-3.0	-1.0	10.6
	1000	-4.0	-4.0	1.0	-6.0	-5.0	-4.0	3.0
	2000	-2.0	-4.0	-6.0	-5.0	-4.0	-4.2	4.8
	4000	9.0	5.0	9.0	7.0	6.0	7.2	16.7
	8000	8.0	13.0	12.0	10.0	7.0	10.0	23.0
#3	250	-5.0	-7.0	-9.0	-6.0	-8.0	-7.0	18.4
	500	6.0	6.0	8.0	6.0	6.0	6.4	18.0
	1000	9.0	8.0	5.0	2.0	6.0	6.0	13.0
	2000	8.0	6.0	4.0	10.0	11.0	7.8	16.8
	4000	6.0	8.0	9.0	9.0	9.0	8.2	17.7
	8000	8.0	11.0	8.0	4.0	2.0	6.6	19.6

*Due to an initial recording error the earphone SPL outputs are 0.1 dB too weak at 250 Hz and 0.1 dB too strong at 500 Hz.

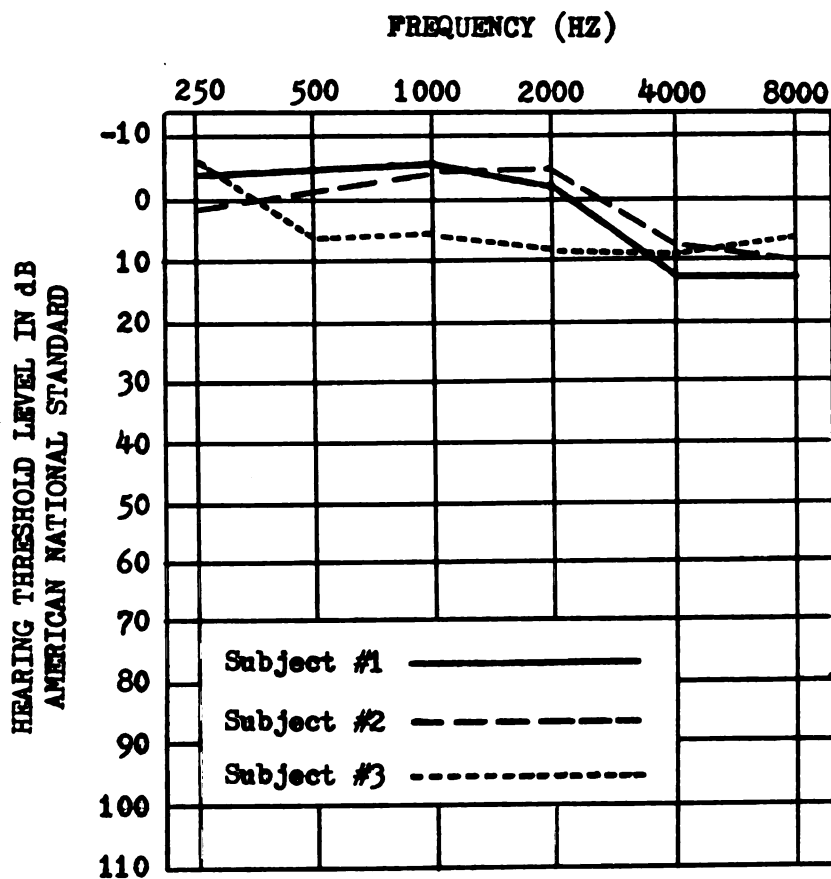


Figure 3. Mean monaural pure-tone air-conduction thresholds for the three subjects used in the experiment. These averages are based on five tests employing descending 2 dB steps of attenuation.

Warble-Tone Threshold Results

Right ear monaural thresholds were obtained for thirty warble-tone combinations and thirty repeated measures for a total of sixty at each of the following center frequencies for each subject: 250, 500, 1000, 2000, 4000, and 8000 Hz. Appendix K gives both the Hearing Threshold Levels (HTL)⁵ and Sound Pressure Levels (SPL) for all subjects under each of the warble-tone combinations for each frequency. The data shows that there is variation in the warble-tone thresholds as a result of both the frequency and the warble-tone combination used. The quantity of numbers representing threshold is too great to display graphically the thresholds for each combination for each subject and for each frequency. However, it is important to view the differences and trends in the warble-tone thresholds as they occurred. To display these differences and trends and derive statistics that could be meaningfully managed, each subject's mean pure-tone air-conduction threshold in SPL was subtracted from that same subject's mean warble-tone threshold in SPL (for each repeated measure combination) for the same frequency. The difference scores that resulted were then averaged and plotted as dB differences from an arbitrary zero reference line representing the pure-tone threshold. The resultant individual subject and mean dB difference scores for each warble-tone combination and frequency are given in Appendix L.

Figures 4a through 9b display graphically these mean dB differences for each warble-tone combination. If at a particular frequency the

⁵HTL for warble-tone threshold is the dial setting re 0 HTL when the audiometer is calibrated for warble-tone. (See appendix D.)

Frequency = 250 Hz

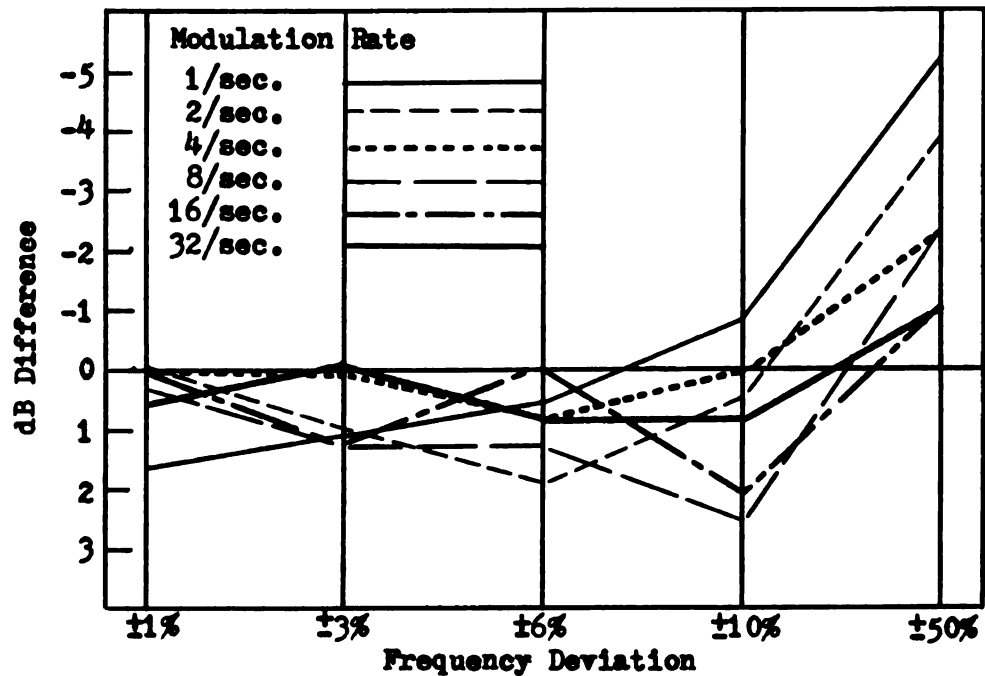


Figure 4a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

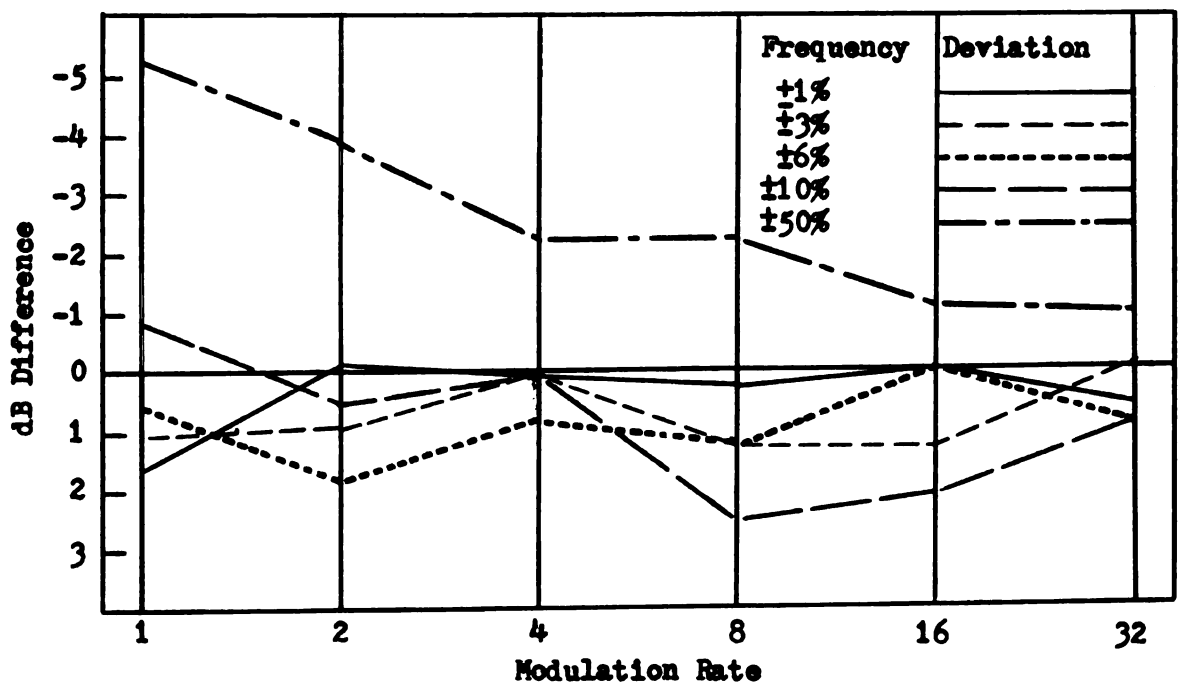


Figure 4b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

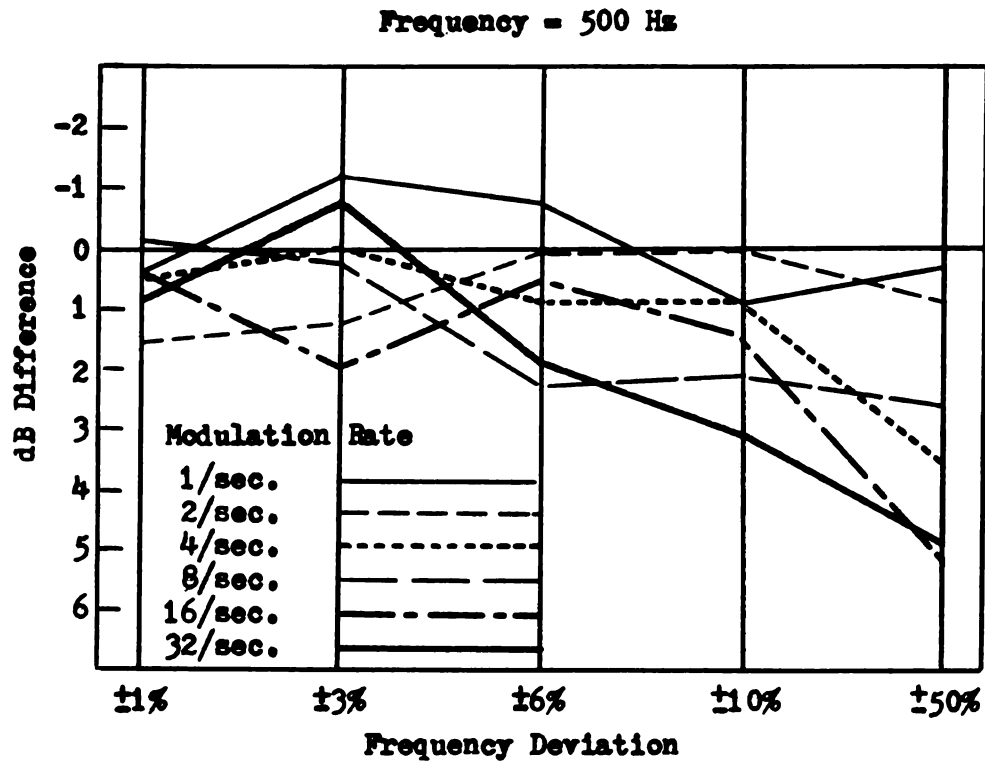


Figure 5a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

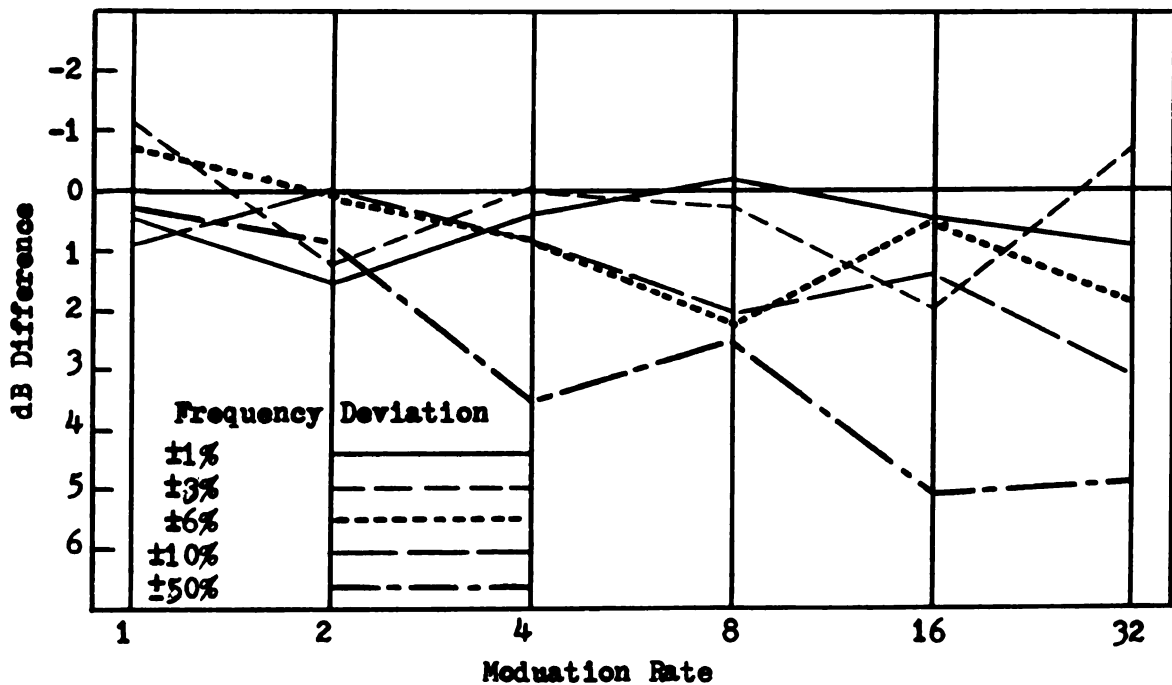


Figure 5b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

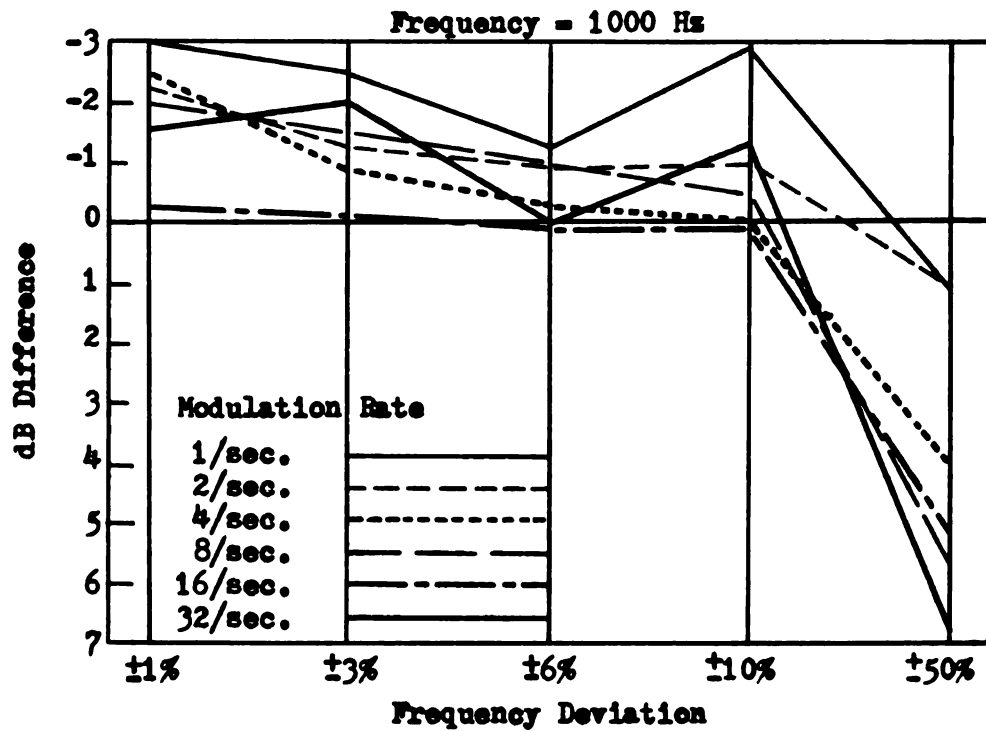


Figure 6a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

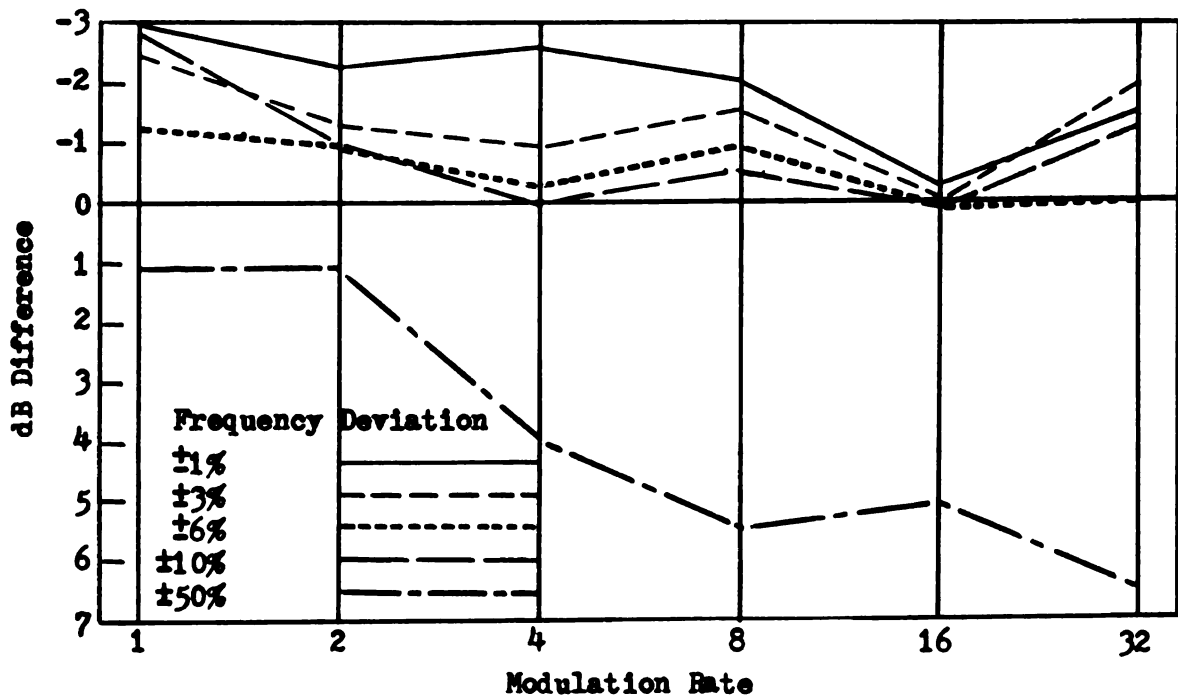


Figure 6b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

Frequency = 2000 Hz

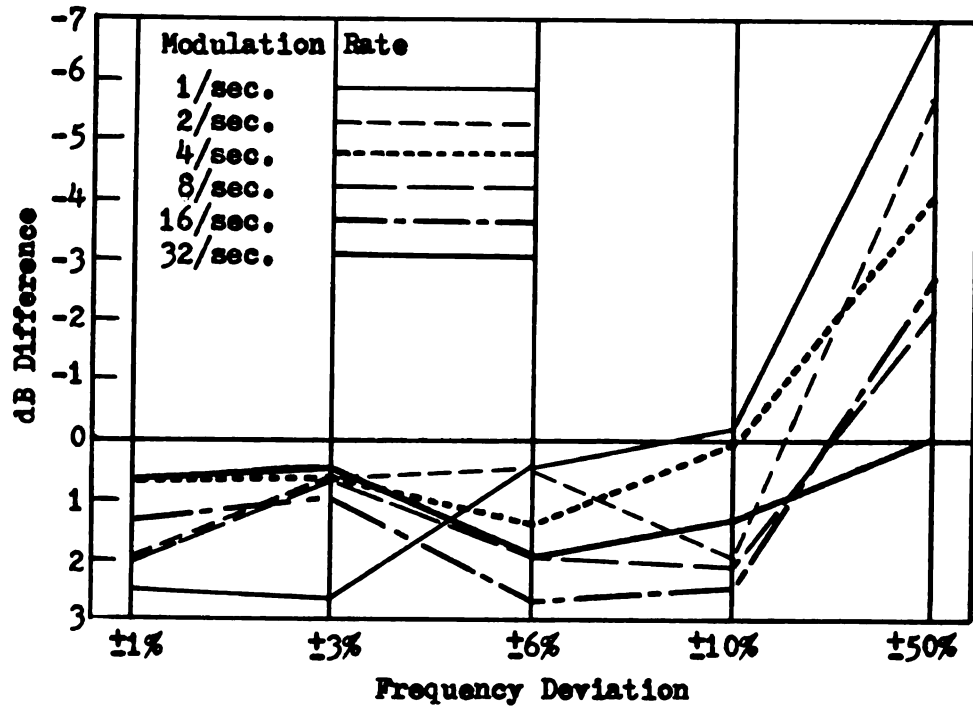


Figure 7a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

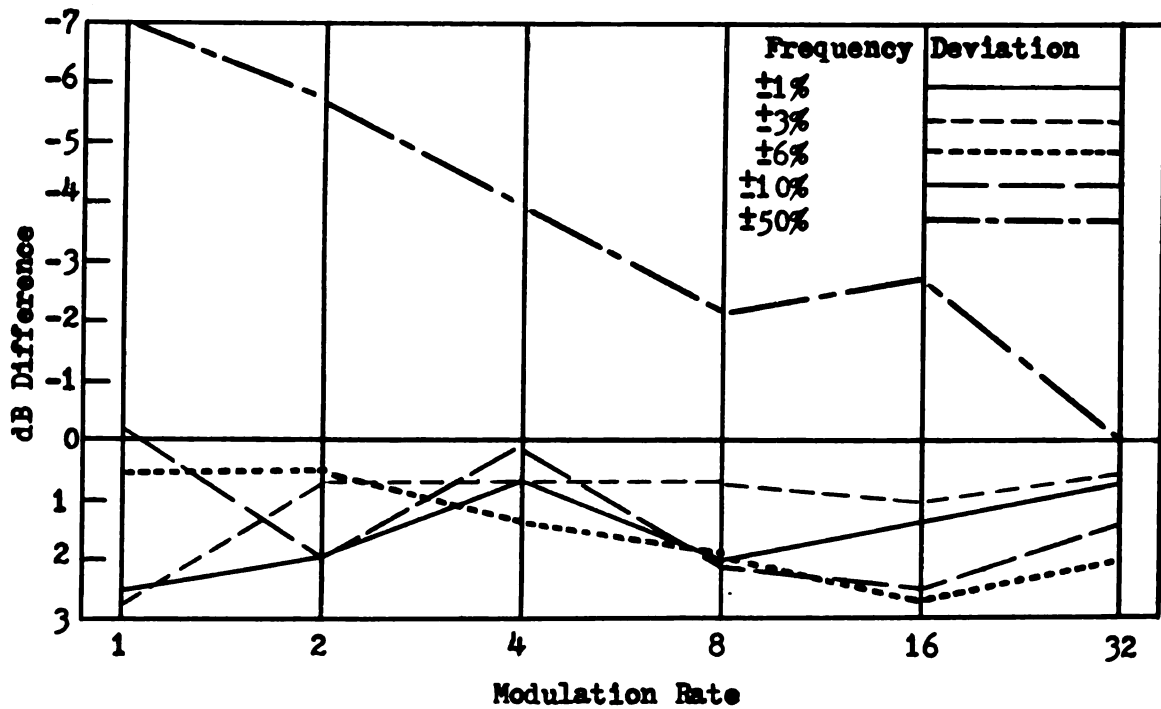


Figure 7b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

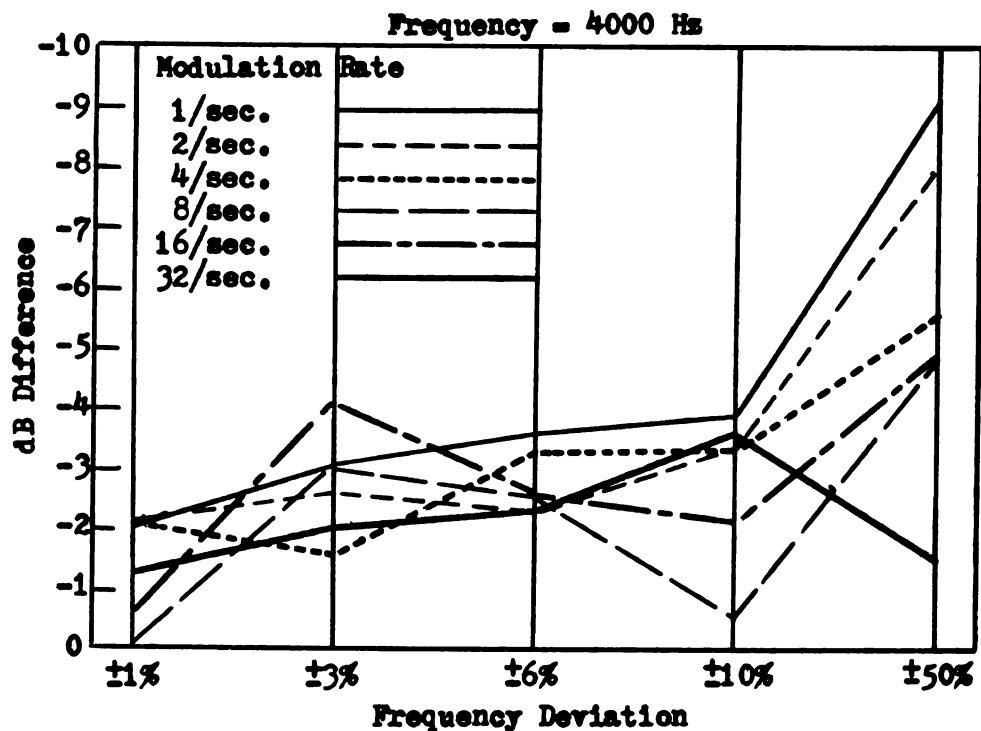


Figure 8a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

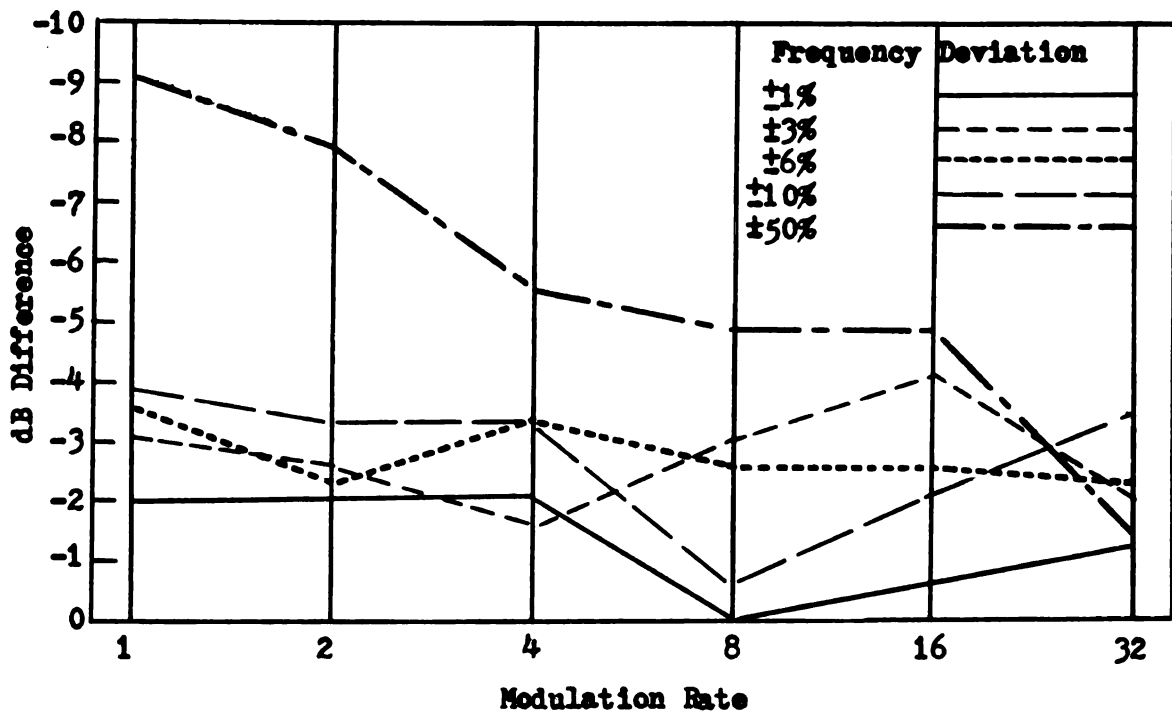


Figure 8b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

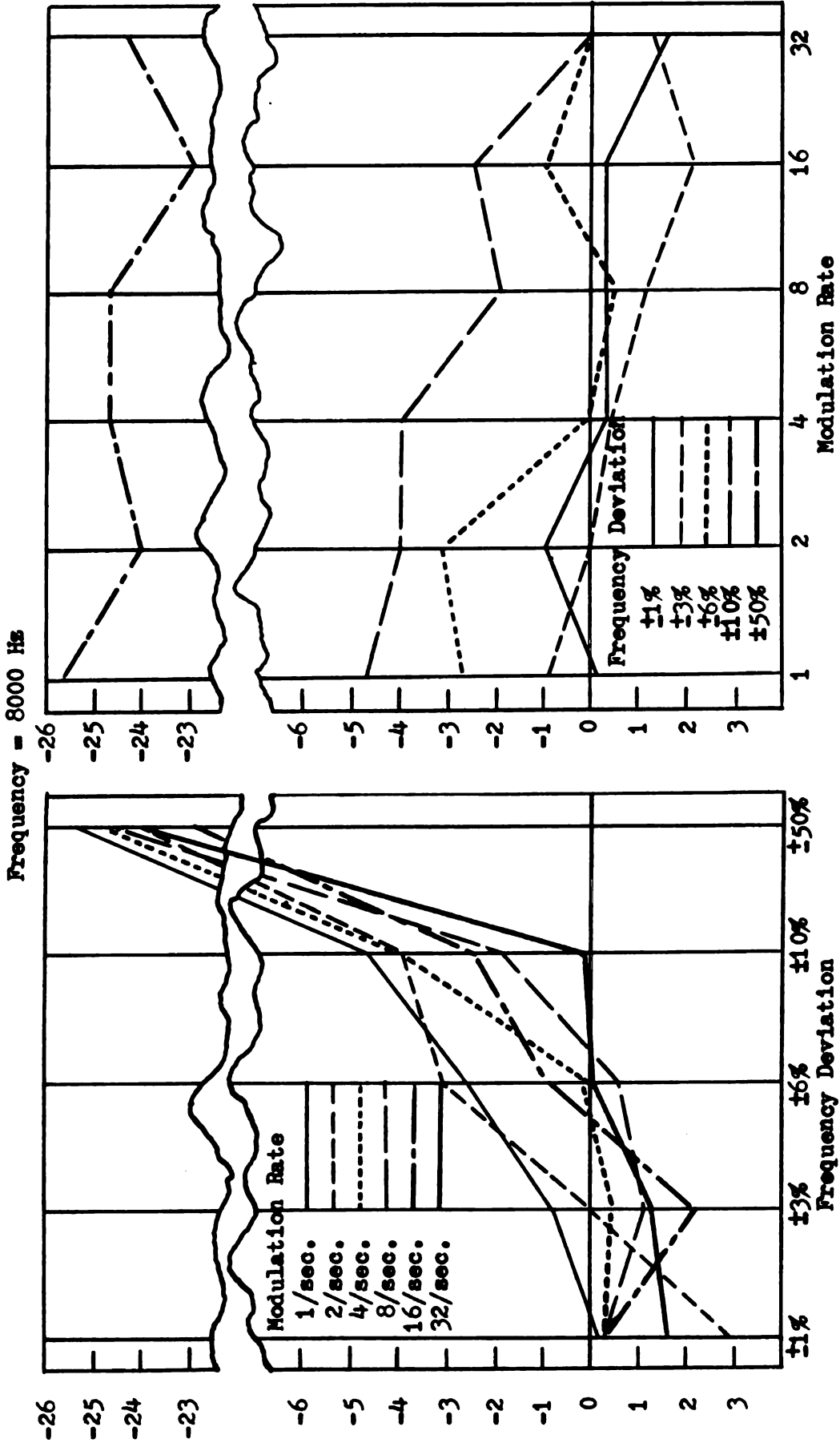


Figure 9a. Mean dB difference scores for each warble-tone frequency deviation with modulation rate as the parameter.

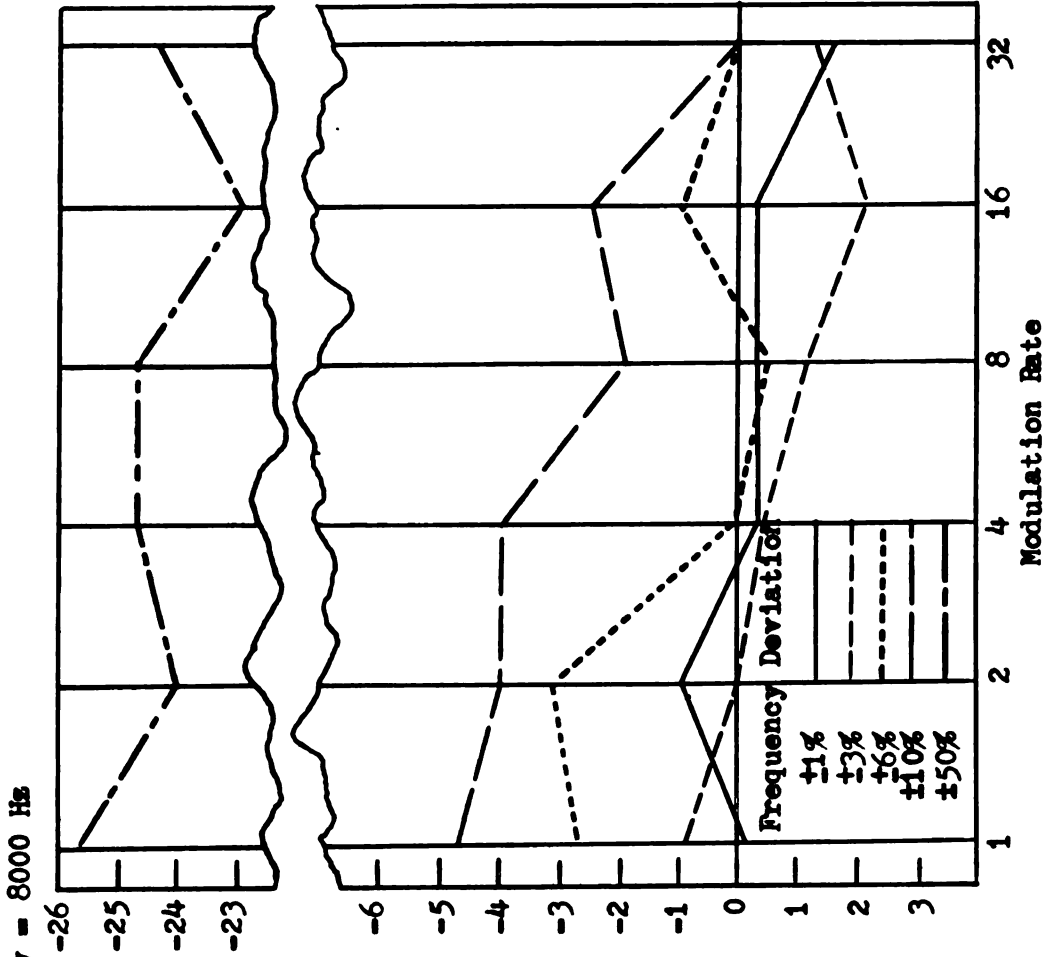


Figure 9b. Mean dB difference scores for each warble-tone modulation rate with frequency deviation as the parameter.

warble-tone threshold was better (required less SPL) than by pure-tone, then the difference shown in Figures 4a through 9b would be negative. Likewise, a positive difference means that the warble-tone is poorer than the pure-tone threshold. The data for each frequency are shown two ways: first, with modulation rate as the parameter and; second, with the frequency deviation as the parameter. A cursory observation of the warble-tone thresholds shows that they are not always comparable to the pure-tone thresholds (represented by the "0" reference line). Also, certain trends occur with respect to the warble-tone combination utilised. A more detailed analysis of the results relative to the original questions of interest now follows.

Warble-Tone Thresholds Versus Frequency

Figures 4a through 9b show that there are variations in warble-tone thresholds as a function of frequency. While the differences are not great (with the exception of the $\pm 50\%$ frequency deviation combinations) warble-tone thresholds are generally poorer than the pure-tone thresholds at 250, 500, and 2000 Hz and better at 1000, 4000, and 8000 Hz.

Threshold is generally poorer at 250 Hz than the pure-tone reference except for the $\pm 50\%$ frequency deviation (Figure 4a) which shows better thresholds. The threshold of the $\pm 50\%$ frequency deviation is also better at low modulation rates than at high modulation rates (Figure 4b) but this does not appear to generalise to the other frequency deviations. If the $\pm 50\%$ frequency deviation condition were excluded at 250 Hz no basic differences in warble-tone thresholds would be apparent.

Warble-tone thresholds are generally poorer than the pure-tone threshold at 500 Hz (Figures 5a and 5b) with the $\pm 50\%$ frequency deviation giving the poorest threshold. Again, if this frequency deviation were excluded from the data, no consistent differences in thresholds for 500 Hz would be evident. There is a tendency, however, for higher modulation rates to result in poorer thresholds at the higher frequency deviations.

At 1000 Hz the warble-tone thresholds are better than the pure-tone thresholds (Figures 6a and 6b). The single notable exception is the $\pm 50\%$ frequency deviation. The effect created by this frequency deviation is most noticeable at the higher modulation rates where a difference (poorer) up to approximately 6 dB occurs between the warble- and pure-tone thresholds. Again, as in the previous frequencies, if the $\pm 50\%$ frequency deviation condition were eliminated, essentially no differences between the warble- and pure-tone thresholds would occur.

Almost all combinations of warble-tone (except the $\pm 50\%$ frequency deviation combinations) resulted in poorer thresholds than obtained by pure-tones at 2000 Hz (Figures 7a and 7b) and a reversal for the direction of change occurs from that seen at 500 and 1000 Hz. The change is that the $\pm 50\%$ frequency deviation condition now gives the best or most sensitive thresholds and is better than the pure-tone threshold. The most sensitive thresholds occur at low modulation rates and decrease in sensitivity at high modulation rates. Again, if the $\pm 50\%$ frequency deviation condition were not included, all of the thresholds would be similar and slightly poorer than the pure-tone thresholds.

At 4000 Hz all warble-tone thresholds are better than the pure-tone reference. In addition, distinct differences in thresholds begin

to appear as a result of the warble-tone combination employed. Figures 8a and 8b show that the most sensitive (best) thresholds are those associated with the $\pm 50\%$ frequency deviation condition and that the least sensitive thresholds are those associated with the $\pm 1\%$ frequency deviation condition. In addition, better thresholds have a tendency to be associated with lower modulation rates.

Distinct differences in threshold due to the warble-tone combination are evident at 8000 Hz (Figures 9a and 9b). In general, warble-tone thresholds tend to be better than their pure-tone counterpart. Differences due to frequency deviation show better thresholds as the frequency deviation increases. Slightly better thresholds are again associated with lower modulation rates.

An interesting phenomenon occurs in the trends associated with warble-tone thresholds. At 250 Hz the general trend is for the wider frequency deviations and lower modulation rates to be associated with the most sensitive thresholds. However, at 500 Hz this trend is somewhat reversed showing a tendency for the wider frequency deviations and higher modulation rates to produce the poorest thresholds. The trend at 500 Hz also holds true at 1000 Hz, and actually becomes more noticeable. At 2000 Hz the trend with warble-tone thresholds is similar to that reported for 250 Hz, and continues through 4000 and 8000 Hz. What this indicates is that there seems to be two "changeover" regions with respect to the types of threshold responses that might be expected; one between 250 and 500 Hz and the other between 1000 and 2000 Hz.

Table 3 shows the mean warble-tone dB difference scores from the pure-tone thresholds and standard deviations for all combinations of frequency deviation and modulation rate at each test frequency. The

Table 3. Mean* warble-tone dB difference thresholds from the pure-tone thresholds and standard deviations for each test frequency.

Frequency in Hz	Mean	Standard Deviation
250	0.06	1.68
500	1.17	1.50
1000	-0.17	2.44
2000	0.36	2.40
4000	-3.04	1.94
8000	-5.37	9.86

*All combinations of frequency deviation and modulation rate were averaged for the three subjects.

order of frequencies having the least to the most variability is as follows: 500, 250, 4000, 2000, 1000, and 8000 Hz.

Warble-Tone Versus Pure-Tone Thresholds

The primary purpose of this investigation was to compare pure-tone and warble-tone hearing thresholds using various combinations of frequency deviations and modulation rates. Figures 4a through 9b show the mean monaural dB difference scores from the pure-tone thresholds and are plotted in two different ways so that threshold effects of the warble-tone combinations used can be seen. Even though the data in those figures have been condensed from the original results, it is still difficult to answer one of the main questions asked by this investigation: "How do warble-tone thresholds at various combinations of modulation rates and frequency deviations compare with conventional, monaural pure-tone thresholds?"

Figures 10, 11, and 12 show the effects of each warble-tone combination on threshold across all test frequencies. The implication from such an analysis would be that the warble-tone combination(s) with the least variability or having a constant variability from the pure-tone thresholds would be best for threshold testing.

In Figure 10 the $\pm 1\%$ frequency deviation with its various modulation rates shows little change in threshold from one frequency to the next with all combinations fairly comparable to the pure-tone thresholds. A possible trend is that of less variability around the pure-tone thresholds with increased modulation rates. However, this speculated reduction in variability is quite small and would probably have little or no effect in clinical testing. The $\pm 3\%$ frequency deviation conditions also show relatively comparable warble- and pure-tone thresholds across all frequencies.

It appears that under the $\pm 6\%$ frequency deviation conditions (Figure 11) that lower frequencies tend to be associated with slightly poorer thresholds than the higher frequencies. This trend becomes more noticeable in the $\pm 10\%$ frequency deviation conditions with threshold improving approximately 5 dB from 250 to 8000 Hz. Further, warble-tone thresholds seem to become poorer with increased modulation rates.

Figure 12 shows the $\pm 50\%$ frequency deviation combinations and it is quite evident that the warble-tone thresholds for each combination vary as a function of frequency. This variation covers a range of approximately 32 dB with 8000 Hz having the greatest variability. In addition, the trend showing poorer thresholds with increased modulation rates (discussed for the $\pm 6\%$ frequency deviation conditions) is more

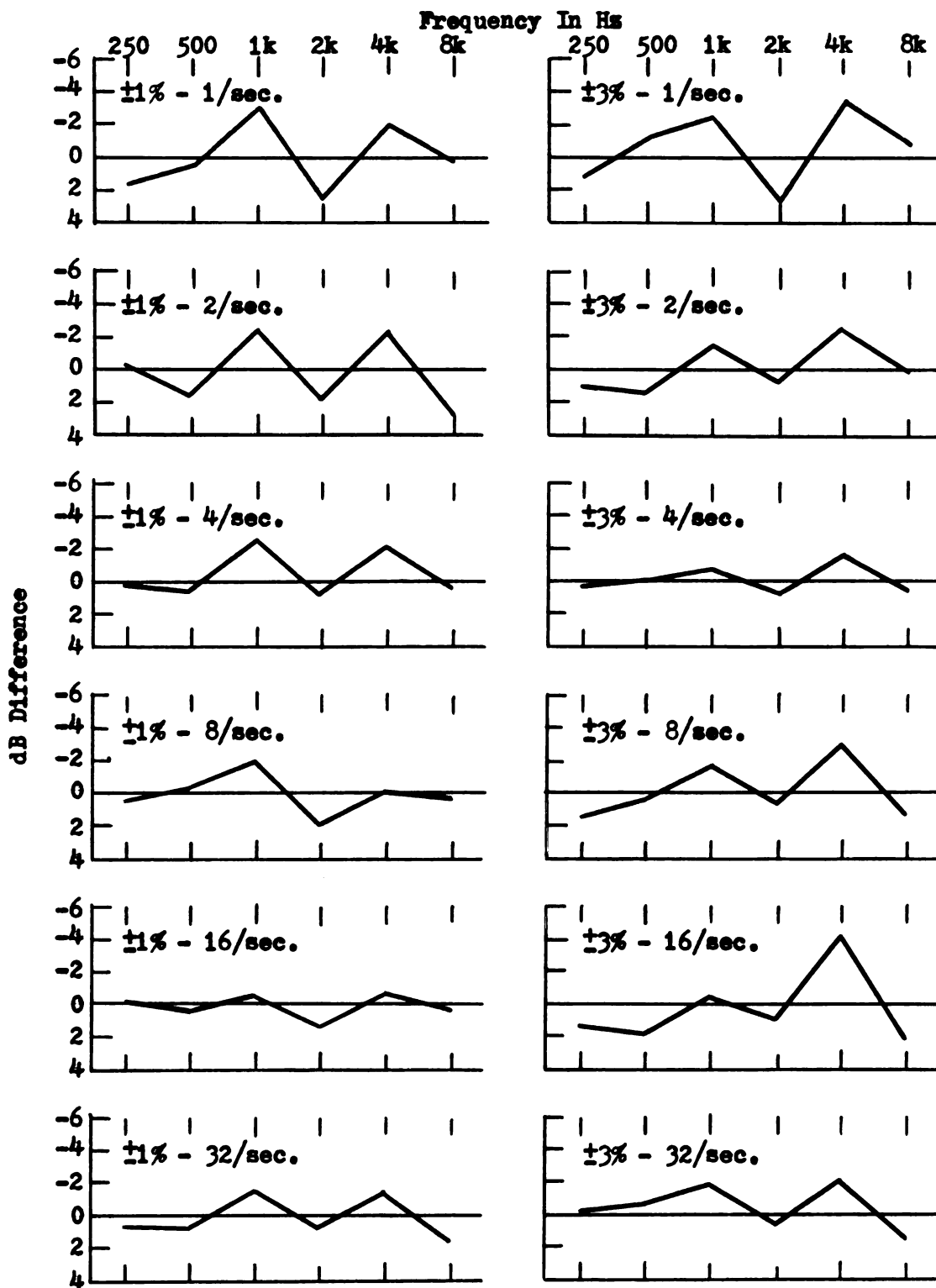


Figure 10. Mean differences in dB between warble-tone and pure-tone thresholds for the warble-tone combinations indicated in each graph.

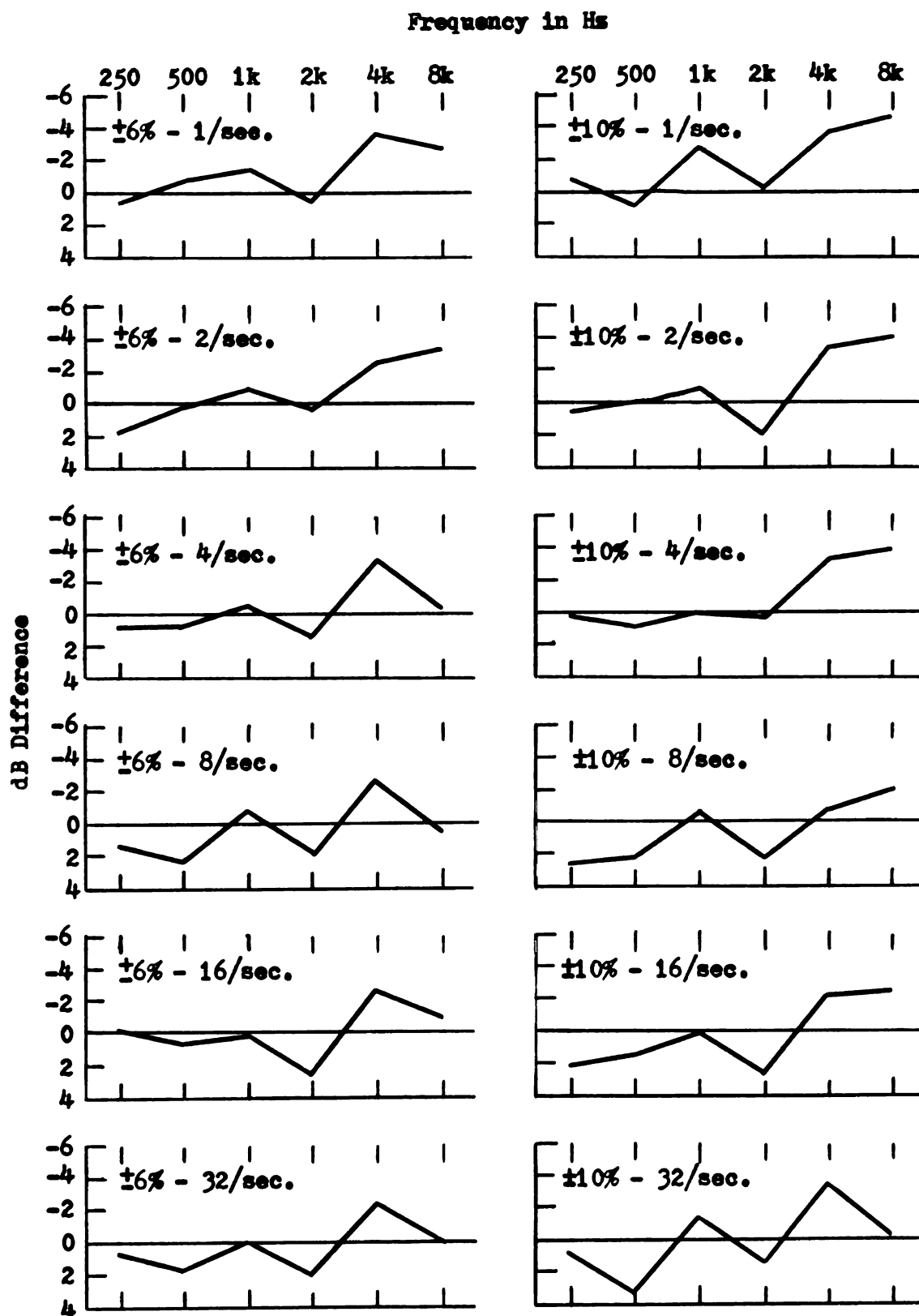


Figure 11. Mean differences in dB between warble-tone and pure-tone thresholds for the warble-tone combinations indicated in each graph.

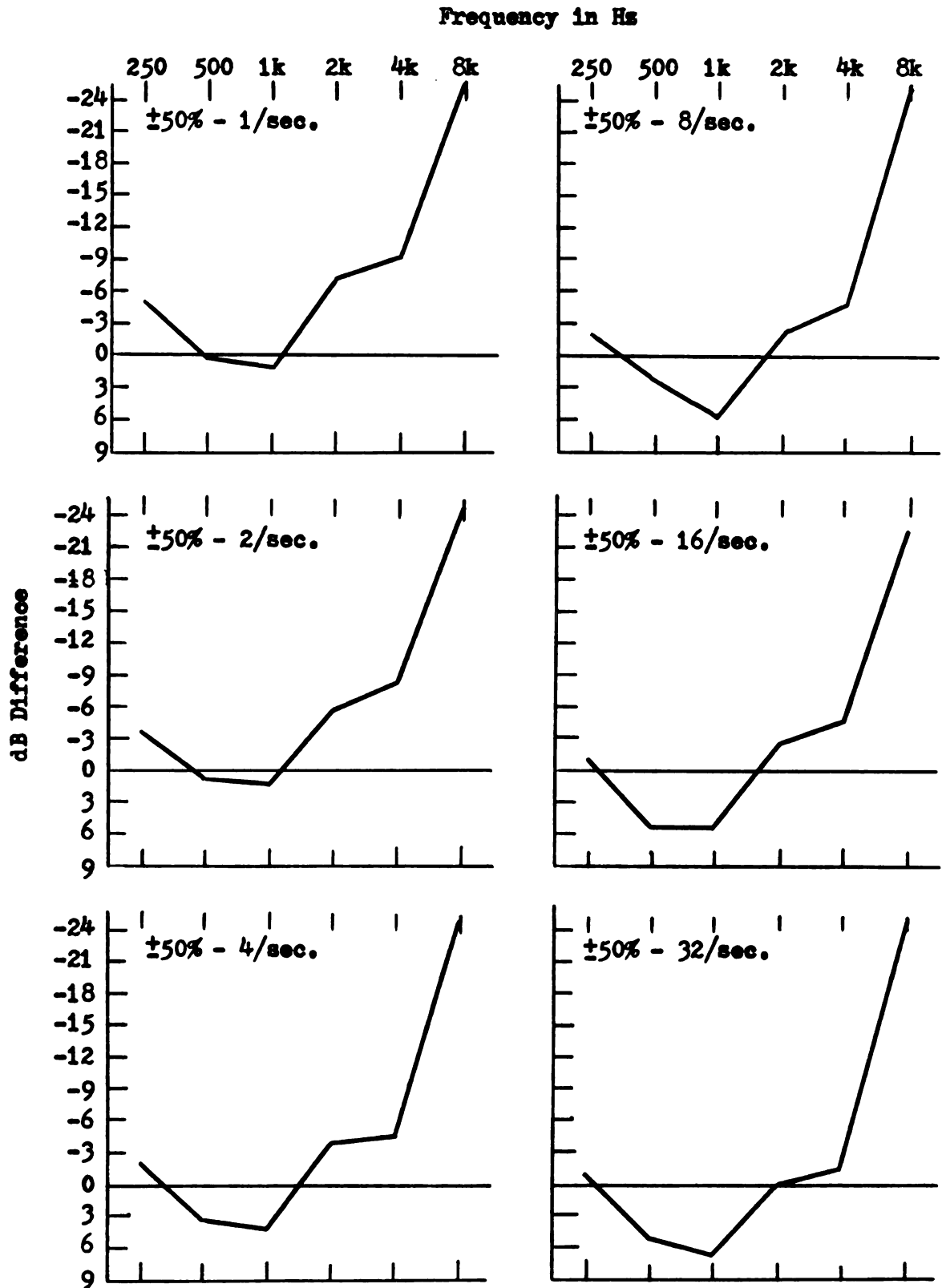


Figure 12. Mean differences in dB between warble-tone threshold and pure-tone threshold for the warble-tone combinations indicated in each graph.

noticeable here except at 8000 Hz. Poorer thresholds by approximately 5 dB occur with modulation rate increases from 1 per second to 32 per second.

In general, the conclusion from the presentation of the thirty warble-tone combinations utilized across frequencies indicates that for all practical purposes, warble-tone combinations up to and including frequency deviations as high as $\pm 10\%$, and modulation rates as rapid as 32 per second result in little or no noticeable differences in warble- and pure-tone thresholds. However, beyond the limits just specified, noticeable differences exist that might preclude the use of various warble-tone combinations in routine hearing testing unless special calibration or correction factors are taken into consideration. Some of these differences (particularly at 8000 Hz and the $\pm 50\%$ frequency deviation) are so great that even normal calibration procedures may not be able to correct earphone sound pressure output levels to account for these differences.

Changes in frequency deviation seem to have greater influence on warble-tone threshold than do changes in modulation rate. With frequency deviation, the effects on threshold have little clinical significance (differences greater than ± 5 dB) until frequency deviations become larger than $\pm 10\%$. With the modulation rates utilized there appears to be little effect on threshold. There seems to be some effect (producing poorer thresholds with increasing rates) at the high frequency deviations but the resulting differences are not large and would be of little significance in routine clinical testing.

Consequently, how do warble-tone thresholds at various combinations of modulation rates and frequency deviations compare with conventional,

monaural pure-tone thresholds? In general, any combination of warble-tone modulation rate and frequency deviation up to and including 32 per second and $\pm 10\%$ respectively should produce good agreement between warble-tone and conventional pure-tone thresholds for normal hearing adults.

Relations Among Warble-Tone Threshold Rankings by Subjects

What are the relations among the threshold rankings of the various warble-tone combinations by the subjects? This question was asked to determine intersubject reliability of warble-tone thresholds. The null hypothesis is that the rankings are unrelated. A measure that allows this kind of association to be determined on more than two sets of rankings is Kendall's Coefficient of Concordance (W) which bears a linear relation to the average correlations taken over all subjects, except that only values between 0 and +1 can occur. The coefficient of concordance is an index of the divergence of the actual agreement in the data from the maximum possible (perfect agreement). Since tied ranks occurred frequently in the warble-tone thresholds and tended to depress the value of W , a correction was introduced which slightly increased the value of W over what it would have been if uncorrected (Siegel, 1956).

Table 4 summarizes the results of the coefficient of concordance for each of the test frequencies and rankings given in Appendix M. With an N larger than 7 ($N = 30$), the probability associated with a calculated Chi square (χ^2) representing W is approximately distributed as Chi square with $N - 1$ degrees of freedom (Siegel, 1956, p. 236).

Table 4. Summary of coefficient of concordance (W) of inter-subject reliability of warble-tone thresholds.

Frequency in Hz	Coefficient of Concordance	Calculated Chi Square Value
250	W = 0.27	23.49
500	W = 0.50*	43.50*
1000	W = 0.76***	66.12***
2000	W = 0.58**	50.46**
4000	W = 0.49*	42.63*
8000	W = 0.74***	64.38***

*p. $\leq$ 0.05

**p. $\leq$ 0.01

***p. $\leq$ 0.001

Results of the coefficient of concordance show that the null hypothesis is rejected ($p. \leq 0.05$) at 500, 1000, 2000, 4000, and 8000 Hz. The interpretation is that the rankings by the subjects for the various warble-tone combinations are related, with the exception of 250 Hz. While the null hypothesis at 250 Hz was not rejected, this was possibly due to subject three's deviation from the threshold pattern exhibited by the other two subjects.

The significant value of W may be interpreted as meaning that the subjects applied essentially the same standard in performing the threshold task with the thirty combinations of warble-tone thresholds. It should be emphasized that a high or significant value of W does not mean that the orderings observed are correct. In fact, they may all be incorrect with respect to some external criterion.

Effects of Modulation Index on Warble-Tone Threshold

It has been suggested that in normal ears for a given modulation index (ratio of frequency deviation in Hz to the modulation rate at a given frequency) better thresholds are obtained with smaller frequency deviations (Dallos and Tillman, 1966; Young and Harbert, 1970).

Dallos and Tillman (1966) initially warned against drawing sweeping generalizations from their data since it was based on one normal hearing subject and a patient with acoustic neurinoma tested at 500 Hz.

Young and Harbert (1970) tested four normal and five subjects having a sensorineural loss at 1000 Hz to attempt to explore further the work of Dallos and Tillman. They concluded:

For a given modulated index, better thresholds were obtained with smaller frequency deviation in normal ears. In abnormally adapting ears, the threshold remained unchanged or increased or decreased for a given modulation index (p.7).

The possibility that an "equivalent modulation index" of 16 as suggested by Dallos and Tillman before stable threshold could be traced in abnormally adapting ears was not confirmed.

Table 5 gives the dB differences between warble- and pure-tone thresholds and the modulation indices (MI) for each of the warble-tone combinations used in this experiment for each frequency. The purpose in examining these data was to determine if the modulation index exerted any influence on the warble-tone thresholds obtained. Even without plotting graphically the data in Table 5 it is clear that with the limited variability in warble-tone thresholds (either across frequency with a single warble-tone combination or within a given frequency with a variety of warble-tone combinations) and with the large range of modulation indices, that there is no systematic effect between modulation

Table 5. Mean warble-tone threshold difference (TD) in dB from the pure-tone threshold along with the modulation indices (MI) for each of the warble-tone combinations used.

Warble-Tone Combination		Frequency in Hz											
		250		500		1000		2000		4000		8000	
		TD	MI	TD	MI	TD	MI	TD	MI	TD	MI	TD	MI
$\pm 1\%$	- 1	1.6	5.0	0.4	10.0	-3.0	20.0	2.5	40.0	-2.0	80.0	0.1	160.0
$\pm 1\%$	- 2	-0.1	2.5	1.6	5.0	-2.3	10.0	1.9	20.0	-2.1	40.0	2.8	80.0
$\pm 1\%$	- 4	0.1	1.2	0.4	2.5	-2.6	5.0	0.7	10.0	-2.1	20.0	0.3	40.0
$\pm 1\%$	- 8	0.3	0.6	-0.2	1.2	-2.0	2.5	2.0	5.0	0.0	10.0	0.3	20.0
$\pm 1\%$	- 16	0.0	0.3	0.4	0.6	-0.3	1.2	1.4	2.5	-0.6	5.0	0.3	10.0
$\pm 1\%$	- 32	0.6	0.1	0.8	0.3	-1.6	0.6	0.7	1.2	-1.3	2.5	1.6	5.0
$\pm 3\%$	- 1	1.1	15.0	-1.2	30.0	-2.5	60.0	2.7	120.0	-3.1	240.0	-0.8	480.0
$\pm 3\%$	- 2	1.0	7.5	1.3	15.0	-1.3	30.0	0.7	60.0	-2.6	120.0	0.0	240.0
$\pm 3\%$	- 4	0.1	3.7	0.0	7.5	-0.8	15.0	0.7	30.0	-1.6	60.0	0.4	120.0
$\pm 3\%$	- 8	1.3	1.8	0.3	3.7	-1.5	7.5	0.7	15.0	-3.0	30.0	1.1	60.0
$\pm 3\%$	- 16	1.3	0.9	1.9	1.8	-0.1	3.7	1.0	7.5	-4.1	15.0	2.1	30.0
$\pm 3\%$	- 32	-0.1	0.4	-0.7	0.9	-2.0	1.8	0.5	3.7	-2.0	7.5	1.3	15.0
$\pm 6\%$	- 1	0.6	30.0	-0.7	60.0	-1.3	120.0	0.5	240.0	-3.6	480.0	-2.7	960.0
$\pm 6\%$	- 2	1.8	15.0	0.1	30.0	-0.8	60.0	0.5	120.0	-2.3	240.0	-3.2	480.0
$\pm 6\%$	- 4	0.8	7.5	0.8	15.0	-0.3	30.0	1.4	60.0	-3.3	120.0	-0.2	240.0
$\pm 6\%$	- 8	1.3	3.7	2.3	7.5	-0.8	15.0	1.9	30.0	-2.6	60.0	0.5	120.0

Table 5 (Continued)

Marble-Tone Combination		Frequency in Hz											
		250		500		1000		2000		4000		8000	
		TD	MI	TD	MI	TD	MI	TD	MI	TD	MI	TD	MI
±6% - 16		0.0	1.8	0.6	3.7	0.1	7.5	2.7	15.0	-2.6	30.0	-1.0	60.0
±6% - 32		0.8	0.9	1.8	1.8	0.0	3.7	2.0	7.5	-2.3	15.0	0.0	30.0
±10% - 1		-0.8	50.0	0.8	100.0	-2.8	200.0	-0.2	400.0	-3.8	800.0	-4.7	1600.0
±10% - 2		0.5	25.0	0.0	50.0	-1.0	100.0	1.9	200.0	-3.3	400.0	-4.0	800.0
±10% - 4		0.1	12.5	0.8	25.0	0.0	50.0	0.2	100.0	-3.3	200.0	-4.0	400.0
±10% - 8		2.5	6.2	2.1	12.5	-0.5	25.0	2.2	50.0	-0.6	100.0	-2.0	200.0
±10% - 16		2.1	3.1	1.4	6.2	0.1	12.5	2.5	25.0	-2.1	50.0	-2.5	100.0
±10% - 32		0.8	1.5	3.1	3.1	-1.3	6.2	1.4	12.5	-3.5	25.0	-0.2	50.0
±50% - 1		-5.3	250.0	0.3	500.0	1.1	1000.0	-7.1	2000.0	-9.1	4000.0	-25.7	8000.0
±50% - 2		-3.8	125.0	0.8	250.0	1.1	500.0	-5.7	1000.0	-7.8	2000.0	-24.2	4000.0
±50% - 4		-2.3	62.5	3.6	125.0	4.0	250.0	-3.9	500.0	-5.6	1000.0	-24.7	2000.0
±50% - 8		-2.3	31.2	2.6	62.5	5.5	125.0	-2.2	250.0	-4.8	500.0	-24.7	1000.0
±50% - 16		-1.1	15.6	5.1	31.2	5.1	62.5	-2.7	125.0	-4.8	250.0	-23.0	500.0
±50% - 32		-1.0	7.8	4.8	15.6	6.6	31.2	0.0	62.5	-1.5	125.0	-24.3	250.0

index size and the dB difference scores. These comments should be reserved at least for the subjects studied (a small sample of normal listeners).

Both Dallos and Tillman (1966) and Young and Harbert (1970) reported that at a given modulation index better thresholds were obtained with smaller frequency deviations. The test frequencies from which these comments were directed were 500 Hz for the former authors and 1000 Hz for the latter. The results of the present investigation indicate that it would be hazardous to generalize those conclusions as shown by Figures 13 and 14. These figures reveal no distinct trends for a given modulation index with the possible exception being 8000 Hz. At this frequency better thresholds tend to occur at a given MI with increased frequency deviation. However, if modulation indices are considered which include the $\pm 50\%$ frequency deviation conditions, better thresholds seem to occur with wider frequency deviations at 250, 2000, 4000, and 8000 Hz. Poorer thresholds at a given MI occur with wider frequency deviations at 500 and 1000 Hz. The latter statement is consistent with the findings of the two studies cited.

With respect to the modulation index and modulation rates, poorer thresholds generally occur with lower modulation indices for all frequencies and frequency deviations.

Upon considering the effects of the modulation index on warble-tone thresholds, no consistent generalization is evident that one or a combination of indices provides a guideline in threshold prediction when testing normal listeners.

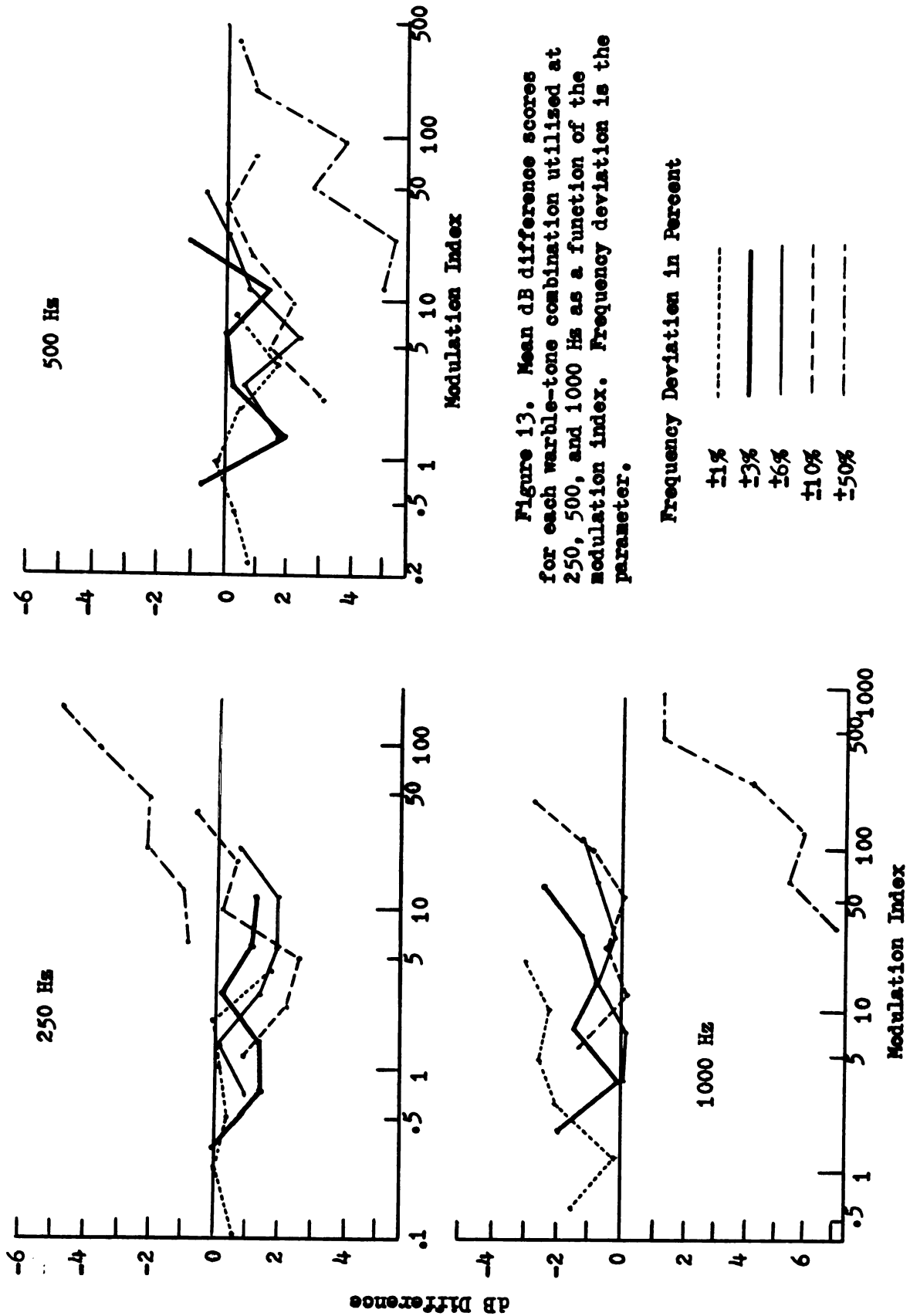


Figure 13. Mean dB difference scores for each warble-tone combination utilized at 250, 500, and 1000 Hz as a function of the modulation index. Frequency deviation is the parameter.

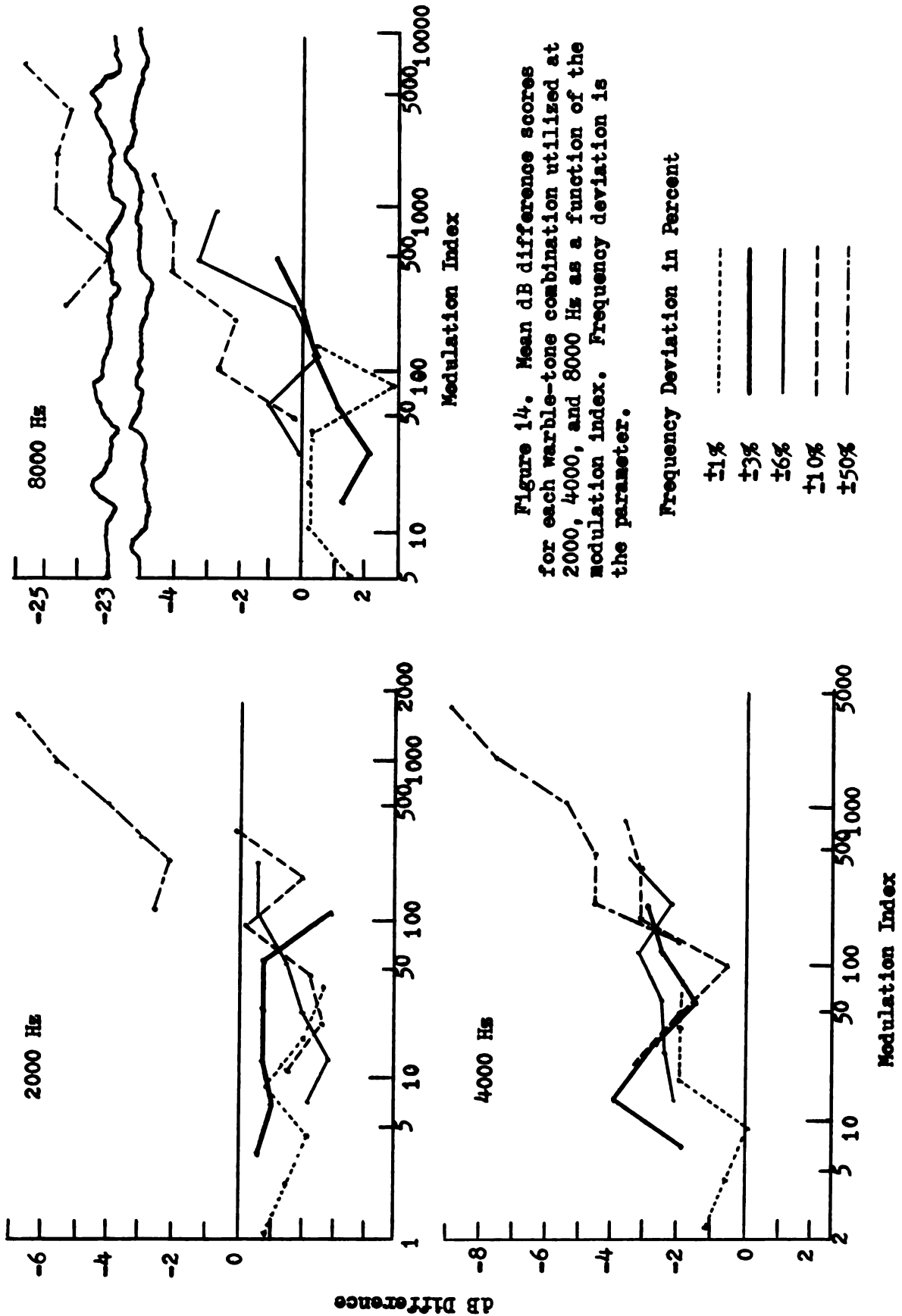


Figure 14. Mean dB difference scores for each warble-tone combination utilized at 2000, 4000, and 8000 Hz as a function of the modulation index. Frequency deviation is the parameter.

Discussion

Due to the small sample size and variation in the range of warble-tone thresholds from the pure-tone thresholds, a question concerning the validity of the findings of this investigation might be raised. It is true that in routine clinical testing much of this range would fall within the clinical error generally accepted of ± 5 dB. However, in warble-tone testing, small differences may be of more clinical significance. Recall, that when the coefficient of concordance was performed to determine the consistency of subjects to rank order thirty combinations of warble-tone at each of the test frequencies, that significance ($p. \leq 0.05$) was exceeded at 500, 1000, 2000, 4000, and 8000 Hz. It is rather noteworthy that this significance level was reached since there was a limited intensity range in which the warble-tone thresholds occurred. Consequently, the results of the coefficient of concordance provide the justification for having confidence in the warble-tone thresholds obtained.

Trends in Warble-Tone Thresholds. It was stated in previous discussion that frequency deviation contributes more than modulation rate to variations in warble-tone threshold. With this in mind it is appropriate to reiterate the distinctive patterns in threshold responses that were found.

At 250 Hz the general trend was for the $\pm 50\%$ frequency deviation condition to result in the best thresholds for all modulation rates. However, at 500 and 1000 Hz this pattern was reversed with the $\pm 50\%$ condition yielding the poorest warble-tone thresholds at all modulation rates. Then, at 2000, 4000, and 8000 Hz, the $\pm 50\%$ condition showed a

pattern similar to that at 250 Hz with better thresholds obtained at all modulation rates. While the frequency deviation pattern of warble-tone thresholds varied as a function of the test frequency, thresholds were always improved at $\pm 50\%$ frequency deviation conditions with lower modulation rates. In the total pattern presented there appears to be two changeover regions--one between 250 and 500 Hz and one again between 1000 and 2000 Hz. A first logical assumption might be that the changes in threshold are related to the minimal audible pressure threshold curve for humans. However, this would imply that under the $\pm 50\%$ frequency deviation conditions better warble-tone thresholds should always be obtained since the audibility curve would be reached at lower sound pressure levels due to the "wide frequency sweep." On the other hand, these differences cannot be explained by individual subject variation since the patterns are consistent across all subjects (except for subject three at 250 and 4000 Hz).

Since large sample consistency in threshold trends and the significance of deviations from these trends is unknown, it is difficult to determine whether subject three or the other two subjects were deviant at 250 and 4000 Hz. At any rate it may be best to consider only the differences in individual patterns at these two frequencies. Because subject three holds a B.A. degree in music, her thresholds might be suspected to reflect a more experienced ability to listen to frequency changes. However, if this were the case the differences that occurred would more logically have been expected for all test frequencies for this subject and this did not happen. In fact, selected warble-tone combinations were repeated with no significant differences in the thresholds obtained.

At this time no feasible explanation for the threshold patterns obtained is offered by this investigator. If the warble-tone threshold patterns are confirmed by subsequent research, it would then be appropriate to speculate about possible acoustical, physiological, or psychological factors or interactions.

Comparisons with Previous Work. Are the results of this investigation consistent with any previous studies comparing warble- and pure-tone thresholds? Sivian and White (1933) had reported that a few check measurements made on the same individual with the warble- and pure-tone indicated no systematic differences between the threshold values other than those due to the physical and psychological considerations the warble-tone was intended to minimize. They used a constant modulation rate of 10 per second and a frequency deviation which progressively changed in percent from approximately $\pm 4.6\%$ at 1100 Hz (± 50 Hz) to approximately $\pm 0.97\%$ at 15,000 Hz (± 146 Hz). The results of the present investigation tend to support their findings under the conditions utilized.

Peck (1970), using a warble-tone having a frequency deviation of 5% to determine auditory thresholds in very young children, commented that it was difficult to give a precise reference level for the warbled sound-field pure-tones. However, it was his impression (based on thresholds obtained on more than 10 normal-hearing young adults) that the thresholds approached the ISO zero reference levels. He did not specify whether the frequency deviation was a $\pm 5\%$ or a $+5\%$ variation and the modulation rate was not given. Regardless, under the possible warble-tone combinations that could have resulted, this investigation supports his comments.

An Allison Laboratory Bulletin A-5 (not dated) and Reilly (1958a), suggested that better thresholds occur with a warble-tone than with a pure-tone stimulus. This investigation does not necessarily lead to the same conclusion. While it is true that certain warble-tone combinations result in better thresholds than produced by pure-tones, this trend is not consistent across all frequencies, and in fact, shows poorer warble-tone thresholds at some frequencies than by pure-tone. A more tenable conclusion would be that warble-tone may act as a more attention centering device and serves to circumvent response difficulties produced by ambient noise and tinnitus, and thus may result in thresholds which are more consistent. However, to say that warble-tone thresholds are better than pure-tone thresholds would be a hazardous supposition. These statements, of course, apply to normal hearing adults only. Warble-tone versus pure-tone thresholds for children and for subjects with auditory pathology await investigation.

Studies specifically comparing warble- and pure-tone thresholds are generally not available with which to relate the results of this research. However, limited data is provided in studies by Dallos and Tillman (1966) and Young and Harbert (1970) comparing warble-tone with pure-tone thresholds at 500 and 1000 Hz. While it is not possible to directly compare the thresholds they obtained with those of the current study (because of different warble-tone combinations, psychophysical method, and signal generating apparatus) there are sufficient similarities to make approximate comparisons.

Dallos and Tillman (1966) found approximately the same or slightly better thresholds with increased frequency deviation at 500 Hz with a single normal listener and better thresholds with slower modulation

rates. The present investigation showed approximately the same or slightly poorer thresholds with increased frequency deviation. While better thresholds with slower modulation rates were also found in this study, the variability was not as divergent as thresholds obtained by Dallos and Tillman.

Young and Harbert (1970) recorded the thresholds of four normal, trained listeners at 1000 Hz and found that thresholds remained about the same or improved slightly with increased frequency deviation. Results of the current investigation at the same frequency do not show any effect with respect to frequency deviation. However, Young and Harbert's contention that better thresholds were obtained with slower modulation rates tends to be confirmed--although the improvement is not as great as obtained in their investigation.

A review of the previous two studies in light of the current investigation depicts some rather interesting comparisons. This study's results do not agree with Dallos and Tillman's at 500 Hz in that poorer thresholds were found with increased frequency deviation. Also, at 1000 Hz it is difficult to detect any consistent differences in thresholds as suggested by Young and Harbert. It is important to remember that the comparisons being made exclude the $\pm 50\%$ frequency deviation conditions since neither of the former studies employed that wide a frequency deviation. The findings concerning modulation rates are consistent across all three studies but differences are not as great in the current investigation. It must be emphasized that the signals used varied somewhat for the three studies compared, in that the other investigations used saw-tooth waveform frequency deviations and this study used sinusoidal waveform deviations. Perhaps the type of waveform

generating the test signal effects warble-tone thresholds in terms of modulation rate and frequency deviation.

The final point that should be made is that there is no reason to expect that changes in thresholds are similar from one frequency to the next. While this aspect should be investigated further, this research suggests that definite differences do exist.

Role of the Modulation Index. Thresholds for a given modulation index in normal listeners seems to provide no significant information or trends with respect to desirable combinations of warble-tone frequency deviation and modulation rate. In fact, a comparison of Figures 13 and 14 with 4b, 5b, 6b, 7b, 8b, and 9b shows that similar information is present except that the abscissa is expanded in the former series of figures.

Summary

In attempting to generalize the findings of this investigation to a larger population care must be taken because of the small sample size involved. However, this does not necessarily mean that the sample size detracts from the general findings presented. Recall, the coefficient of concordance did reach statistical significance demonstrating that intersubject reliability of warble-tone thresholds was good.

In general, substantial agreement was found between warble- and pure-tone thresholds. However, differences were found for some stimulus parameter conditions. These differences varied by test frequency and warble-tone combination (frequency deviation and modulation rate). The results demonstrated that changes in frequency deviation had a greater influence on threshold than changes in modulation rate. This was

particularly noticeable for the $\pm 50\%$ frequency deviation conditions. While threshold changes related to frequency deviation were not consistent across frequencies, lower modulation rates generally resulted in better thresholds for a given frequency deviation at all test frequencies.

Poorer thresholds generally were found with lower modulation indices (frequency deviation divided by modulation rate) for all frequencies and frequency deviations. In contrast to previous investigations, no evidence was found to support the notion that one or a combination of modulation indices provides a guideline for threshold prediction when testing normal hearing adult listeners.

Intersubject reliability of warble-tone thresholds was good ($p. \leq 0.05$). In addition, variability in warble-tone thresholds was small with the exception of 8000 Hz.

In general, warble-tone combinations up to and including frequency deviations of $\pm 10\%$ and modulation rates as fast as 32 per second resulted in close agreement (± 5 dB) between warble- and pure-tone thresholds for normal hearing adults.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Warble-tone stimulus parameters of frequency deviation and modulation rate were investigated to determine their effect on hearing threshold.

Three normal-hearing experienced listeners were individually administered thirty randomized warble-tone combinations and thirty repeated measures (for a total of sixty) at each of six octave frequencies from 250 through 8000 Hz. The thresholds obtained were then compared with the same subject's conventional, pure-tone air-conduction thresholds. Each subject's hearing threshold levels were measured monaurally on six separate occasions, with one frequency tested per session utilizing a 2 dB step descending method.

The data were subjected to descriptive and statistical analyses to answer the questions originally posed. Descriptive measures were employed to explore the significance of one variable over another in contributing to warble-tone thresholds and their comparison with pure-tone results. The coefficient of concordance was utilized to determine intersubject reliability of warble-tone thresholds.

The results showed that up to and including frequency deviations and modulation rates of $\pm 10\%$ and 32 per second respectively, little difference between the two methods of threshold measurement can be

expected under clinical conditions with normal adult listeners. However, beyond these warble-tone combinations, variations in threshold are expected to occur and correction factors should be applied to the obtained thresholds if they are to substitute for pure-tone measurements.

Conclusions

The following conclusions seem warranted:

1. Warble-tone thresholds are not always comparable to pure-tone thresholds. Their comparison depends on the test frequency and warble-tone combination being tested. In general, warble-tone thresholds are poorer than pure-tone thresholds at 250, 500, and 2000 Hz and better at 1000, 4000, and 8000 Hz.
2. There appear to be two "changeover" regions with respect to the types of warble-tone threshold responses expected, one between 250 and 500 Hz and the other between 1000 and 2000 Hz. The direction of threshold response reverses in these regions and is most noticeable with the wider frequency deviations.
3. Variability in warble-tone thresholds is small as a function of frequency with the exception of 8000 Hz.
4. Intersubject reliability of warble-tone thresholds is good but some individual subject variability was found.
5. No evidence suggests that one or a combination of modulation indices provides a guideline in threshold prediction when testing normal adult listeners; however, poorer thresholds generally occur with lower modulation indices for all frequencies and frequency deviations.
6. Changes in frequency deviation, within limits, seem to have greater influence on warble-tone threshold than do changes in modulation

rate. However, while changes in frequency deviation are not consistent from one frequency to the next, lower modulation rates generally result in better thresholds for a given frequency deviation.

7. Warble-tone combinations up to and including frequency deviations and modulation rates of $\pm 10\%$ and 32 per second result in little or no clinically noticeable differences between warble- and pure-tone thresholds for normal hearing adults.

Recommendations for Future Research

While certain patterns of warble-tone threshold were found in this investigation, their confirmation is desirable utilizing a larger adult sample on a limited number of selected combinations of frequency deviation and modulation rate.

Additional frequency deviations and waveforms might be evaluated which were not included in this initial study. For example, fewer from the $\pm 1\%$ to $\pm 10\%$ and more between the $\pm 10\%$ and $\pm 50\%$ frequency deviation range could be evaluated. A smaller number of modulation rates could be used, although the extremes of the range should be tested. Further, a comparison of thresholds should be performed using warble-tones produced by triangular, positive pulse, negative pulse, positive ramp, negative ramp, and sawtooth waveforms.

Warble-tone thresholds under earphones should be compared to sound-field thresholds on an adult population. This would provide additional information relative to the warble-tone's clinical usefulness.

The clinical utility of warble-tone (utilizing various combinations of frequency deviation and modulation rate) should be systematically examined using a large group of subjects representing various types of

auditory pathology (e.g. conductive, cochlear, retrocochlear, and central lesions). Representative response patterns could hopefully be established for the various types of auditory pathologies and thus used in differential diagnosis.

After basic warble-tone parameters have been established with adults, several experiments should be replicated with children. Additional questions that should be asked are: Does warble-tone result in more consistent thresholds than the conventional pure-tone stimulus? Is the warble-tone a better attention-centering auditory signal for children than conventional pure-tones? Can the warble-tone be applied more successfully with young children than conventional pure-tone audiometry?

A possible clinically useful extension of warble-tone study in sound-field is its use in hearing aid evaluations, especially with children and those with language problems. By comparing the unaided sound-field discrete frequency warble-tone thresholds with aided sound-field thresholds, information relative to the use gain of the hearing aid can be obtained.

The Sensorineural Acuity Level (SAL) test described by Jerger and Tillman (1960) has generated interest as a method to quantify the status of the sensorineural mechanism. While the procedure is simple to employ, it is limited in its application because of two problems. First, the occlusion effect results in underestimating low frequency cochlear reserve in conductive hearing loss cases. Secondly, cases with sensorineural losses are likely to be overmasked due to "spread of masking" resulting in overestimating SAL thresholds particularly in the high frequency region. A study could be conducted to determine whether

warble-tone can be used in sound-field SAL testing with the warble-tone serving as the tonal stimulus. Hopefully, this method would circumvent the occlusion effect problem mentioned above. The usefulness of sound-field SAL employing spondee words has already been demonstrated by Rintelmann and Johnson (1970). The warble-tone SAL studies should be performed initially under earphones (conventional) and then in sound-field. Normal hearing adult subjects should be tested first followed by pathological ears and then its feasibility should be investigated with children.

In summary, warble-tone audiometry should prove to be a useful audiological tool for a variety of clinical applications. However, before this technique can become a routine part of the audiologists' test battery, a series of studies must first be completed. Some of these basic investigations have been mentioned above.

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APPENDICES

APPENDIX A

AMBIENT NOISE LEVELS IN TEST ROOM

AMBIENT NOISE LEVELS IN TEST ROOM

Table A1. Octave band and C-scale analyses of ambient noise levels in examination room (fan on) in dB SPL according to the standards set forth by the American Standards Association (ASA S3.1-1960).

Test Room - IAC 1200-ACT					Sound Level Meter - B&K 2204					
Microphone - B&K 4145					Octave Band Filter Set - B&K 1613					
Center Frequency in Hz										
C-Scale		31.5	63	125	250	500	1000	2000	4000	8000
dB SPL	45	34	44	26	<10	<10	<10	<10	<10	<10

APPENDIX B

RATIONALE AND PROCEDURES FOR CALIBRATION OF THE WARBLE-TONE SIGNAL

RATIONALE AND PROCEDURES FOR CALIBRATION OF THE WARBLE-TONE SIGNAL

Calibration of Warble-Tone

There are no accepted or consistent standards on which to base warble-tone calibration (Staab and Rintelmann, 1971). Since the subjective loudness of a sound does not parallel its physical intensity, because of both intensity and frequency (Fletcher and Munson, 1933), it would seem desirable to calibrate the warble-tone so that the loudness is constant in the total test frequency range. However, to do this would require that there be an understanding of the frequency deviations and modulation rates necessary to equate the loudness at the various frequencies. Since this information is not known, it seemed desirable to calibrate the center or base frequency of the warble-tone through the ACCESSORY INPUT of the MA-24 audiometer without any "warble" in a manner similar to that advocated by the American National Standards Institute (S3.6-1969). The effect of this was that the sound pressure level (SPL) outputs obtained were not the same as those for pure-tones because the ACCESSORY INPUT of the MA-24 audiometer was calibrated to a 19 dB SPL at "0" VU. However, with the SPL output of the pure-tone and the center frequency of the signal to be warbled known, (after the input Hearing Threshold Level dial setting had been subtracted) it was a simple matter to allow for the SPL differences and make appropriate comparisons of the hearing thresholds obtained. This was done by

determining the SPL outputs for "0" Hearing Threshold Level for both the warble- and pure-tones and adding or subtracting that value to the measured Hearing Threshold Levels.

This procedure can be used with any audiometer as long as the SPL outputs and Hearing Threshold Level dial inputs are known for both the pure-tones and the center frequencies of the unmodulated warble-tones.

Tables A3 and A4 reflect the pre- and post-experiment SPL outputs obtained for both the pure-tones and unmodulated warble-tones. These values would most likely change for other instrumentation.

It was mandatory that the exact center frequencies, modulation rates and frequency deviations utilized during the testing procedures be specified. The following indicates how this was done.

Calibration of Center Frequency. This refers to the unmodulated center frequency obtained from the B&K 1013 beat-frequency oscillator. Since it was a sine wave the frequency counter (Bekman Eput and Timer, Model 6148) was utilized to set the frequency by varying the FINE SCALE FREQUENCY ALIGNMENT of the beat-frequency oscillator until the frequency counter recorded the frequency desired.

Calibration of Modulation Rate. An independent function generator (Hewlett-Packard Model 1033A) externally drove the beat-frequency oscillator to generate the various modulation rates used. For example, if the function generator produced a 5 Hz signal, the modulation rate was 5 per second. Consequently, the modulation rates were easily determined by reading a frequency counter connected to the output of the function generator.

Calibration of Frequency Deviation. Calibration of frequency deviation was performed using a Tektronix Type 3L5 Spectrum Analyzer Plug-in Unit designed for use with the Tektronix Type 564B Model 121N oscilloscope. The analyzer displayed signal amplitude as a function of frequency deviation and stability of amplitude of the warble-tones.

The basic procedure utilized in frequency deviation determination involved the manipulation of a DISPERSION knob on the Tektronix Type 3L5 Spectrum Analyzer Plug-in Unit which allowed for the selection of a certain value of Hz/DIVision on the visual display area of the oscilloscope. The value of the warble-tone frequency deviation desired at a given time was manually varied by manipulating the FREQUENCY DEVIATION knob on the B&K 1013 beat-frequency oscillator along with the output voltage of the external function generator until the display fell within the predetermined scale selected on the oscilloscope and outlined by the graticule divisions. Figure A1 gives an example of a $\pm 10\%$ frequency deviation at 1000 Hz and Figure A2 shows a $\pm 10\%$ frequency deviation at 8000 Hz.

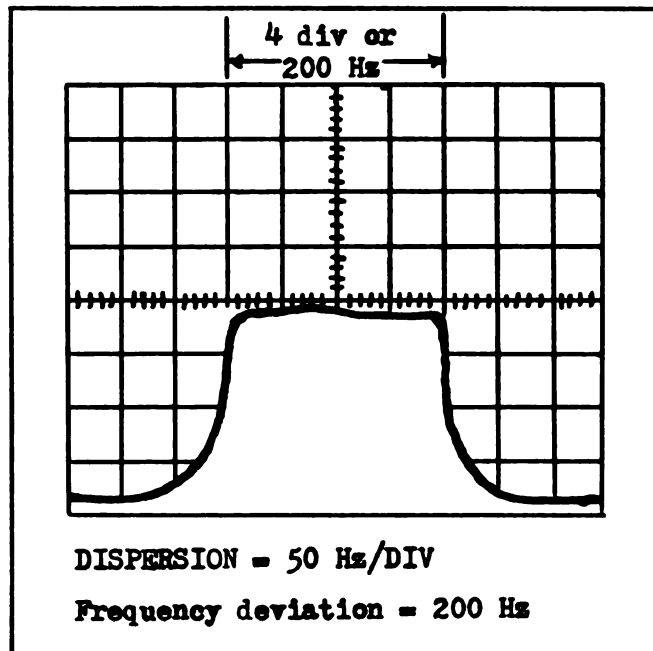


Figure A1. Visual display on an oscilloscope produced by a spectrum analyzer showing a $\pm 10\%$ frequency deviation centered around a base frequency of 1000 Hz.

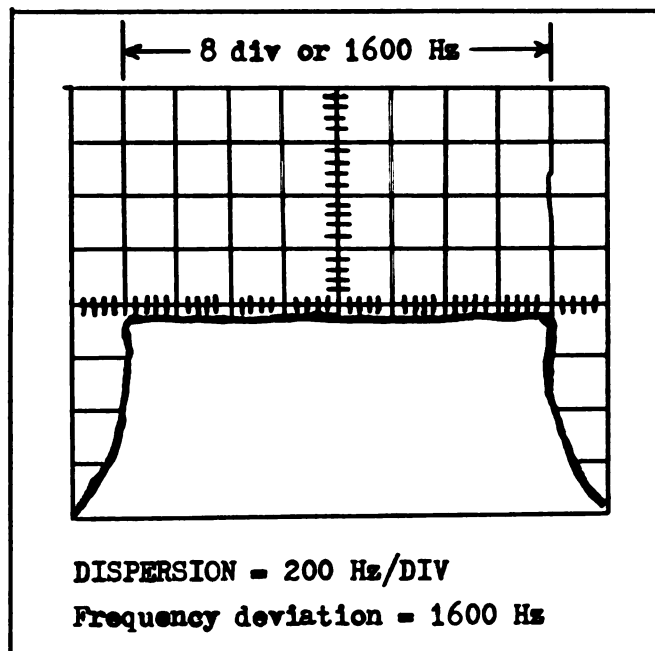


Figure A2. Visual display on an oscilloscope produced by a spectrum analyzer showing a $\pm 10\%$ frequency deviation centered around a base frequency of 8000 Hz.

APPENDIX C

LINEARITY OF MAICO MA-24 AUDIOMETER ATTENUATOR

LINEARITY OF MAICO MA-24 AUDIOMETER ATTENUATOR

A check of the linearity of the audiometer attenuator was performed acoustically with the test earphone attached to a B&K artificial ear and associated sound level meter and octave band filter set. While the ANSI-1969 Standard (S3.6-1969) indicates that "Measures for compliance with this requirement shall be made electrically at the input to the earphone . . .," it was not possible with the system utilized, to measure the electrical signals at low Hearing Threshold Level settings because of the internal noise of the instrumentation. Consequently, a modified version of checking audiometer attenuator linearity was utilized which permitted these measurements to be made acoustically. The rationale and procedure for the technique follows:

Rationale and Procedure

The reason for measuring audiometer attenuation is to ensure that changes in the Hearing Threshold Level dial result in comparable sound pressure changes in the earphone. As long as these changes occur in a linear fashion (within given tolerances) throughout the entire range of the attenuator, it can be assumed that the attenuator is functioning properly and in fact will result in appropriate sound pressure changes. Since the difficulties with noise usually encountered in making these measurements acoustically (and in this experiment also electrically), occur at maximum attenuation, a probable solution appeared to be to

shift the SPL scale upward on the Hearing Threshold Level dial. This was achieved by externally sending a 1000 Hz tone through the ACCESSORY INPUT of the audiometer. This input was calibrated to 19 dB for a "0" VU reading and consequently allowed for approximately an additional 20 dB range over which to test the linearity of the attenuator--even though the noise levels had not changed. This procedure is similar to that advocated for checking the Range and Intervals of Hearing Threshold Levels for Speech (ANSI S3.6-1969) except that the measurement is made acoustically rather than electrically. In a good sound-treated room (as was utilized in this experiment) acoustical measurements down to approximately -20 dB on the Hearing Threshold Level dial can be performed. The values recorded in Table A2 indicate that the Hearing Threshold Dial is linear down to -15 dB if the ANSI criterion is utilized (did not differ by more than 0.3 of the dial interval measured in dB).

A by-product of this modification is that at the upper end of the Hearing Threshold Level dial the maximum power output of the audiometer is reached at approximately 95 dB HTL. However, to check for linearity above this, measurements can be made through the regular pure-tone system.

In the current study thresholds were obtained in 2 dB steps by use of a six position VERNIER on the MA-24 audiometer which changes the Hearing Threshold Level output in 1 dB steps through a range of 5 dB. The audiometer also allows for a -20 dB loss pad in series with the Hearing Threshold Level control. Although not shown in tabular form, acoustical and electrical linearity checks of both of these controls indicated that they provided appropriate changes in sound pressure.

Table A2. Pre- and post-experimental linearity of Maico MA-24 audiometer attenuator made acoustically at the test earphone.

Audiometer = Maico MA-24			Artificial Ear = B&K 4152	
Audiometer Channel = Right			Sound Level Meter = B&K 2204	
Earphone = Right (TDH-39/10Z)			Microphone = B&K 4144	
Earphone Cushion = MX-41/AR			Octave Band Filter Set = B&K 1613	
<u>dB HTL</u>	Pre-experiment		Post-experiment	
	1000 Hz		1000 Hz	
	<u>dB SPL</u>	<u>dB dif</u>	<u>dB SPL</u>	<u>dB dif</u>
95	115.4		115.7	
90	110.7	4.7	111.1	4.6
85	105.8	4.9	106.1	5.0
80	101.0	4.8	101.4	4.7
75	95.9	5.1	96.2	5.2
70	91.1	4.8	91.4	4.8
65	86.0	5.1	86.4	5.0
60	81.2	4.8	81.6	4.8
55	76.1	5.1	76.4	5.2
50	71.3	4.8	71.6	4.8
45	66.2	5.1	66.5	5.1
40	61.4	4.8	61.7	4.8
35	56.2	5.2	56.6	5.2
30	51.4	4.8	51.8	4.8
25	46.3	5.1	46.7	5.1
20	41.5	4.8	41.8	4.9
15	36.4	5.1	36.7	5.1
10	31.5	4.9	31.9	4.8
5	26.4	5.1	26.8	5.1
0	21.6	4.8	22.2	4.6
-5	17.2	4.4	18.1	4.1
-10	12.6	4.6	13.6	4.5
-15	8.5	4.1	9.0	4.6
-20	5.5	3.0	7.0	2.0

APPENDIX D

EARPHONE OUTPUT DATA

Table A3. Pre-experiment audiometer earphone output data for the right earphone of the Malco MA-24 audiometer for (1) the output measured for the pure-tone stimuli, and (2) the output measured for the unmodulated warble-tone stimuli center frequencies. The pure-tone measurements were made according to the American National Standards Institute (ANSI S3.6-1969).

Normal Calibration Level*			Microphone Correction	Corrected Calibration Level		Right Earphone Measured Values for Right Channel					
Test Tone Frequency in Hz	Pure-Tone	Warble-Tone**		Pure-Tone	Warble-Tone	Pure-Tone	Error	Correction	Warble-Tone	Error	Correction
250	95.4	81.4	---	95.4	81.4	95.6	+0.2	---	81.4	---	---
500	81.6	81.5	---	81.6	81.5	81.4	-0.2	---	81.5	---	---
1000	77.0	81.5	---	77.0	81.5	76.4	-0.6	---	81.5	---	---
2000	79.0	79.2	---	79.0	79.2	79.5	+0.5	---	79.2	---	---
4000	79.5	84.5	-0.8	78.7	83.7	78.4	-0.3	---	83.7	---	---
8000	83.0	67.0	+2.0	85.0	69.0	84.5	-0.5	---	69.0	---	---

*All calibrations and measured dB levels are taken re 0.0002 dynes/cm².

****The "normal calibration levels" listed for the warble-tone are not standardized. These levels were obtained by measuring the SPL outputs of the unmodulated warble-tone center frequencies at "0" VU reading at a 60 dB Hearing Threshold Level setting through the ACCESSORY INPUT of the MA-24 audiometer.**

NOTE: Due to an initial recording error the earphone SPL outputs are 0.1 dB too weak at 250 Hz and 0.1 dB too strong at 500 Hz for the pure-tone data.

Year	1990	1991	1992	1993	1994	1995
1990	1	1	1	1	1	1
1991	1	1	1	1	1	1
1992	1	1	1	1	1	1
1993	1	1	1	1	1	1
1994	1	1	1	1	1	1
1995	1	1	1	1	1	1

[illegible]

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1. The first group of variables, *demographic*, includes age, sex, and marital status. The second group, *education*, includes years of schooling and the highest level of education completed. The third group, *employment*, includes whether the respondent is currently employed, the type of job, and the number of hours worked per week. The fourth group, *income*, includes the respondent's annual income and the number of people in the household. The fifth group, *health*, includes the respondent's self-rated health and whether they have any chronic conditions. The sixth group, *social capital*, includes the respondent's level of trust in others and their participation in community activities. The seventh group, *psychological*, includes the respondent's level of life satisfaction and their mental health. The eighth group, *behavioral*, includes the respondent's smoking status, alcohol consumption, and exercise habits. The ninth group, *environmental*, includes the respondent's access to green spaces and their perception of the quality of the environment. The tenth group, *policy*, includes the respondent's knowledge of and support for environmental policies. The eleventh group, *community*, includes the respondent's sense of community and their involvement in local organizations. The twelfth group, *future*, includes the respondent's expectations for the future and their willingness to take action to improve the environment. The thirteenth group, *other*, includes any other variables that may be relevant to the study.

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 84

1. *Journal of the American Medical Association*, 1997; 277: 1033-1036.

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1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 26

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1. *Chlorophyll a* (Chl *a*)

Table A4. Post-experiment audiometer earphone output data for the right earphone of the Maico MA-24 audiometer for (1) the output measured for the pure-tone stimuli, and (2) the output measured for the unmodulated warble-tone stimuli center frequencies. The pure-tone measurements were made according to the American National Standards Institute (ANSI S3.6-1969).

| Audiometer = Malico MA-24 | | | Cushion Type = MX-41/AR | | | Sound Level Meter = B&K 2204 | | | | | |
|--|---------------------------|---------------|---------------------------|-----------------------------|-------------|--|-------|------------|-------------|-------|------------|
| Earphone Type = TDH-39/10Z | | | Microphone = B&K 4144 | | | Octave Band Filter Set = B&K 1613 | | | | | |
| | | | Artificial Ear = B&K 4152 | | | | | | | | |
| Earphone Output Check at 70 dB Hearing Threshold Level for Pure-Tones and at 60 dB Hearing Threshold Level and "0" VU Reading for Unmodulated Warble-Tone Center Frequencies | | | | | | | | | | | |
| Test Tone Frequency in Hz | Normal Calibration Level* | | Microphone Correction | Corrected Calibration Level | | Right Earphone Measured Values for Right Channel | | | | | |
| | Pure-Tone | Warble-Tone** | | Pure-Tone | Warble-Tone | Pure-Tone | Error | Correction | Warble-Tone | Error | Correction |
| 250 | 95.4 | 81.4 | --- | 95.4 | 81.4 | 95.4 | 0.0 | --- | 80.8 | -0.6 | --- |
| 500 | 81.6 | 81.5 | --- | 81.6 | 81.5 | 81.0 | -0.6 | --- | 81.4 | -0.1 | --- |
| 1000 | 77.0 | 81.5 | --- | 77.0 | 81.5 | 76.3 | -0.7 | --- | 81.4 | -0.1 | --- |
| 2000 | 79.0 | 79.2 | --- | 79.0 | 79.2 | 78.8 | -0.2 | --- | 79.3 | +0.1 | --- |
| 4000 | 79.5 | 84.5 | -0.8 | 78.7 | 83.7 | 78.5 | -0.2 | --- | 83.8 | +0.1 | --- |
| 8000 | 83.0 | 67.0 | +2.0 | 85.0 | 69.0 | 84.0 | -1.0 | --- | 68.3 | -0.7 | --- |

*All calibrations and measured dB levels are taken re 0.0002 dynes/cm².

**The "normal calibration levels" listed for the warble-tone are not standardized. These levels were obtained by measuring the SPL outputs of the unmodulated warble-tone center frequencies at "0" VU reading at a 60 dB Hearing Threshold Level setting through the ACCESSORY INPUT of the MA-24 audiometer.

NOTE: Due to an initial recording error the earphone SPL outputs are 0.1 dB too weak at 250 Hz and 0.1 dB too strong at 500 Hz for the pure-tone data.

APPENDIX E

HARMONIC DISTORTION DATA

Table A6. Post-experimental harmonic distortion measurements of the fundamental for test frequencies used in the study. Measurements were made for the right earphone and right channel of the Maico MA-24 audiometer under two conditions: (1) that for the pure-tones generated by the Maico MA-24 and (2) that for the unmodulated warble-tone center frequencies through the right channel and right earphone of the Maico MA-24 audiometer. Measurements were made in compliance with the American National Standards Institute (ANSI S3.6-1969).

| | | | | | | |
|----------------------------------|-------|-------|-------------------------------|-------|-------|------|
| Audiometer = Maico MA-24 | | | Microphone = B&K 4144 | | | |
| Earphone Type = TDH-39/10Z | | | Artificial Ear = B&K 4152 | | | |
| Cushion Type = MX-41/AR | | | Cathode Follower = B&K 2617 | | | |
| | | | Frequency Analyzer = B&K 2107 | | | |
| Harmonic Distortion Measurements | | | | | | |
| Condition #1 | | | | | | |
| Frequency in Hz | 250 | 500 | 1000 | 2000 | 4000 | 8000 |
| SPL of Fundamental | 102.6 | 110.7 | 106.1 | 109.8 | 103.9 | 86.7 |
| SPL with Fundamental Rejected* | 68.8 | 79.5 | 70.2 | 75.3 | 66.6 | 52.5 |
| Dif. in dB | 33.8 | 31.2 | 35.9 | 34.5 | 37.3 | 34.2 |
| Condition #2 | | | | | | |
| SPL of Fundamental | 113.1 | 115.7 | 115.6 | 112.6 | 105.8 | 95.3 |
| SPL with Fundamental Rejected* | 74.6 | 75.9 | 82.0 | 76.0 | 61.9 | 52.3 |
| Dif. in dB | 38.5 | 39.8 | 33.6 | 36.6 | 43.9 | 43.0 |

*These values represent the total SPL remaining after the fundamental has been rejected.

APPENDIX F

RISE AND DECAY TIME DATA FOR AUDIOMETER INTERRUPTER

RISE AND DECAY TIME DATA FOR AUDIOMETER INTERRUPTER

Table A7. Pre- and post-experimental rise and decay times as measured for pure-tones generated by the Maico MA-24 audiometer. The times were measured from the right channel of the audiometer with the assistance of a storage oscilloscope. Measurements were made in compliance with the American National Standards Institute (ANSI S3.6-1969).

| Audiometer = Maico MA-24
Storage Oscilloscope = Tektronix Type 564B
Earphone Jack = Right

Rise and Decay Time Measurements of the Tone Signals | | | | |
|---|-------------------------|--------------|--------------------------|--------------|
| Frequency in Hz | Pre-Experimental Values | | Post-Experimental Values | |
| | Rise Time* | Decay Time** | Rise Time* | Decay Time** |
| 250 | 40 msec. | 45 msec. | 40 msec. | 50 msec. |
| 500 | 40 msec. | 50 msec. | 50 msec. | 45 msec. |
| 1000 | 45 msec. | 40 msec. | 55 msec. | 50 msec. |
| 2000 | 35 msec. | 50 msec. | 45 msec. | 45 msec. |
| 4000 | 35 msec. | 40 msec. | 50 msec. | 50 msec. |
| 8000 | 55 msec. | 55 msec. | 50 msec. | 50 msec. |

*Time for SPL to rise from -20 dB to -1 dB re its final steady value.
 **Time for SPL to decay by 20 dB.

APPENDIX G

BONE-CONDUCTION CALIBRATION DATA

BONE-CONDUCTION CALIBRATION DATA

Table A8. Bone-conduction calibration data recorded according to the norms specified by the Hearing Aid Industry Conference (HAIC) Interim Bone-Conduction Thresholds for Audiometry (Lybarger, 1966).

| | | | | | | |
|---|-----------------------------------|---|--------|---------|---------|---------|
| Audiometer = Maico MA-24
Bone Vibrator = Radiocar B-70-A
Microphone amp. = B&K 2603 | | Artificial Mastoid = Beltone Model M5A
Artificial Mastoid Amp. = Beltone Model M5A | | | | |
| Bone-Conduction Calibration Check | | | | | | |
| Attenuator Settings: 25 dB for 250 Hz and 45 dB for 500, 1000, 2000, and 4000 Hz | | | | | | |
| | Frequency in Hz | 250 Hz | 500 Hz | 1000 Hz | 2000 Hz | 4000 Hz |
| 1. | Actual millivolt reading | 26.1 | 178.0 | 21.6 | 10.2 | 6.17 |
| 2. | Computed dB level re 1 millivolt* | 28.3 | 44.7 | 26.5 | 20.1 | 15.7 |
| 3. | Expected dB reading | 28.4 | 45.1 | 26.7 | 20.2 | 15.8 |
| 4. | Line 2 minus Line 3 | -0.1 | -0.4 | -0.2 | -0.1 | -0.1 |
| 5. | Correction | 0 | 0 | 0 | 0 | 0 |

*To obtain dB level use the following computation: $\text{dB} = 20 \log \frac{(\text{millivolt reading})}{1 \text{ millivolt}}$

APPENDIX H

TEST FREQUENCY CHECKS

TEST FREQUENCY CHECKS

Table A9. Pre- and post-experimental frequency checks of the test frequencies of the Maico MA-24 audiometer performed in compliance with the American National Standards Institute (ANSI S3.6-1969).*

| | | | |
|---|--------------------------------|---|--------------------------|
| Audiometer = Maico MA-24
Channel = Right | | Voltmeter = B&K 2409
Frequency Counter = Bekman 6148 | |
| Pre-experiment Frequency Checks | | | |
| Test
Frequency
in Hz | Measured
Frequency
in Hz | Difference
in Hz | Difference
in percent |
| 250 | 254 | +4 | 1.6% |
| 500 | 503 | +3 | 0.6% |
| 1000 | 1006 | +6 | 0.6% |
| 2000 | 2008 | +8 | 0.4% |
| 4000 | 4000 | 0 | 0.0% |
| 8000 | 7998 | -2 | 0.02% |
| Post-experiment Frequency Checks | | | |
| 250 | 252 | +2 | 0.8% |
| 500 | 499 | -1 | 0.2% |
| 1000 | 1003 | +3 | 0.3% |
| 2000 | 2006 | +6 | 0.3% |
| 4000 | 4001 | +1 | 0.02% |
| 8000 | 8002 | +2 | 0.02% |

*The unmodulated warble-tone center frequencies were observed during all testing and were manually varied so that they were within three percent of the indicated frequency.

APPENDIX I

RANDOMIZED PRESENTATION ORDER FOR WARBLE-TONE STIMULI

RANDOMIZED PRESENTATION ORDER FOR WARBLE-TONE STIMULI

Table A10. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #1.

| Center Frequency = 1000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 3% | 4/sec. | | 16. 10% | 16/sec. | | 31. 6% | 2/sec. | | 46. 10% | 1/sec. | |
| 2. 50% | 32/sec. | | 17. 10% | 1/sec. | | 32. 6% | 16/sec. | | 47. 3% | 32/sec. | |
| 3. 10% | 2/sec. | | 18. 1% | 32/sec. | | 33. 1% | 1/sec. | | 48. 6% | 32/sec. | |
| 4. 6% | 16/sec. | | 19. 50% | 1/sec. | | 34. 3% | 16/sec. | | 49. 1% | 2/sec. | |
| 5. 6% | 1/sec. | | 20. 3% | 8/sec. | | 35. 3% | 1/sec. | | 50. 50% | 8/sec. | |
| 6. 6% | 2/sec. | | 21. 1% | 2/sec. | | 36. 1% | 16/sec. | | 51. 6% | 8/sec. | |
| 7. 10% | 8/sec. | | 22. 50% | 1/sec. | | 37. 6% | 1/sec. | | 52. 6% | 4/sec. | |
| 8. 10% | 4/sec. | | 23. 1% | 32/sec. | | 38. 6% | 32/sec. | | 53. 3% | 4/sec. | |
| 9. 1% | 8/sec. | | 24. 3% | 32/sec. | | 39. 10% | 4/sec. | | 54. 1% | 4/sec. | |
| 10. 10% | 2/sec. | | 25. 1% | 4/sec. | | 40. 1% | 1/sec. | | 55. 3% | 16/sec. | |
| 11. 6% | 4/sec. | | 26. 10% | 32/sec. | | 41. 10% | 16/sec. | | 56. 3% | 8/sec. | |
| 12. 10% | 32/sec. | | 27. 1% | 8/sec. | | 42. 50% | 4/sec. | | 57. 50% | 32/sec. | |
| 13. 50% | 2/sec. | | 28. 6% | 8/sec. | | 43. 50% | 8/sec. | | 58. 10% | 8/sec. | |
| 14. 50% | 2/sec. | | 29. 1% | 16/sec. | | 44. 50% | 4/sec. | | 59. 3% | 1/sec. | |
| 15. 3% | 2/sec. | | 30. 50% | 16/sec. | | 45. 3% | 2/sec. | | 60. 50% | 16/sec. | |

Table A11. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #2.

| Center Frequency = 2000 Hz | | | | | | | | | | | |
|----------------------------|----|---------|---------|----|---------|---------|----|---------|---------|----|---------|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 50% | | 4/sec. | 16. 6% | | 16/sec. | 31. 1% | | 2/sec. | 46. 10% | | 2/sec. |
| 2. 1% | | 4/sec. | 17. 50% | | 32/sec. | 32. 10% | | 4/sec. | 47. 10% | | 8/sec. |
| 3. 3% | | 4/sec. | 18. 10% | | 1/sec. | 33. 50% | | 4/sec. | 48. 6% | | 8/sec. |
| 4. 1% | | 4/sec. | 19. 50% | | 16/sec. | 34. 50% | | 8/sec. | 49. 6% | | 4/sec. |
| 5. 10% | | 16/sec. | 20. 1% | | 8/sec. | 35. 3% | | 32/sec. | 50. 50% | | 16/sec. |
| 6. 1% | | 1/sec. | 21. 6% | | 1/sec. | 36. 10% | | 8/sec. | 51. 3% | | 8/sec. |
| 7. 3% | | 1/sec. | 22. 50% | | 1/sec. | 37. 50% | | 2/sec. | 52. 3% | | 1/sec. |
| 8. 3% | | 2/sec. | 23. 6% | | 32/sec. | 38. 10% | | 32/sec. | 53. 50% | | 2/sec. |
| 9. 50% | | 32/sec. | 24. 1% | | 8/sec. | 39. 6% | | 2/sec. | 54. 3% | | 32/sec. |
| 10. 6% | | 32/sec. | 25. 1% | | 16/sec. | 40. 6% | | 1/sec. | 55. 1% | | 32/sec. |
| 11. 3% | | 16/sec. | 26. 50% | | 8/sec. | 41. 10% | | 4/sec. | 56. 10% | | 2/sec. |
| 12. 10% | | 32/sec. | 27. 1% | | 32/sec. | 42. 1% | | 2/sec. | 57. 3% | | 8/sec. |
| 13. 50% | | 1/sec. | 28. 1% | | 16/sec. | 43. 3% | | 16/sec. | 58. 6% | | 4/sec. |
| 14. 1% | | 1/sec. | 29. 3% | | 2/sec. | 44. 6% | | 16/sec. | 59. 3% | | 4/sec. |
| 15. 6% | | 8/sec. | 30. 10% | | 1/sec. | 45. 6% | | 2/sec. | 60. 10% | | 16/sec. |

Table A12. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #3.

| Center Frequency = 4000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 4/sec. | | 16. 3% | 16/sec. | | 31. 1% | 1/sec. | | 46. 50% | 32/sec. | |
| 2. 6% | 32/sec. | | 17. 6% | 2/sec. | | 32. 6% | 4/sec. | | 47. 1% | 32/sec. | |
| 3. 3% | 1/sec. | | 18. 3% | 1/sec. | | 33. 1% | 16/sec. | | 48. 1% | 1/sec. | |
| 4. 50% | 4/sec. | | 19. 50% | 8/sec. | | 34. 1% | 8/sec. | | 49. 50% | 8/sec. | |
| 5. 1% | 2/sec. | | 20. 3% | 32/sec. | | 35. 6% | 8/sec. | | 50. 6% | 1/sec. | |
| 6. 10% | 32/sec. | | 21. 3% | 8/sec. | | 36. 3% | 32/sec. | | 51. 6% | 32/sec. | |
| 7. 6% | 2/sec. | | 22. 50% | 32/sec. | | 37. 10% | 4/sec. | | 52. 10% | 8/sec. | |
| 8. 10% | 1/sec. | | 23. 50% | 4/sec. | | 38. 1% | 8/sec. | | 53. 10% | 16/sec. | |
| 9. 6% | 1/sec. | | 24. 10% | 8/sec. | | 39. 10% | 16/sec. | | 54. 3% | 8/sec. | |
| 10. 3% | 16/sec. | | 25. 50% | 2/sec. | | 40. 3% | 4/sec. | | 55. 50% | 1/sec. | |
| 11. 6% | 16/sec. | | 26. 10% | 1/sec. | | 41. 50% | 16/sec. | | 56. 3% | 2/sec. | |
| 12. 50% | 1/sec. | | 27. 1% | 2/sec. | | 42. 6% | 16/sec. | | 57. 1% | 16/sec. | |
| 13. 6% | 8/sec. | | 28. 3% | 2/sec. | | 43. 50% | 16/sec. | | 58. 1% | 4/sec. | |
| 14. 50% | 2/sec. | | 29. 6% | 4/sec. | | 44. 3% | 4/sec. | | 59. 10% | 4/sec. | |
| 15. 10% | 32/sec. | | 30. 1% | 32/sec. | | 45. 10% | 2/sec. | | 60. 10% | 2/sec. | |

Table A13. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #4.

| Center Frequency = 8000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 16/sec. | | 16. 10% | 32/sec. | | 31. 50% | 16/sec. | | 46. 1% | 32/sec. | |
| 2. 1% | 2/sec. | | 17. 3% | 16/sec. | | 32. 1% | 32/sec. | | 47. 10% | 32/sec. | |
| 3. 3% | 1/sec. | | 18. 10% | 4/sec. | | 33. 6% | 1/sec. | | 48. 6% | 32/sec. | |
| 4. 6% | 32/sec. | | 19. 6% | 4/sec. | | 34. 1% | 2/sec. | | 49. 3% | 2/sec. | |
| 5. 10% | 16/sec. | | 20. 3% | 16/sec. | | 35. 10% | 1/sec. | | 50. 50% | 32/sec. | |
| 6. 10% | 8/sec. | | 21. 1% | 8/sec. | | 36. 6% | 16/sec. | | 51. 10% | 16/sec. | |
| 7. 1% | 1/sec. | | 22. 10% | 8/sec. | | 37. 3% | 4/sec. | | 52. 50% | 4/sec. | |
| 8. 50% | 1/sec. | | 23. 50% | 8/sec. | | 38. 50% | 4/sec. | | 53. 50% | 8/sec. | |
| 9. 10% | 1/sec. | | 24. 3% | 4/sec. | | 39. 1% | 8/sec. | | 54. 3% | 2/sec. | |
| 10. 6% | 1/sec. | | 25. 3% | 32/sec. | | 40. 6% | 2/sec. | | 55. 3% | 8/sec. | |
| 11. 50% | 2/sec. | | 26. 10% | 2/sec. | | 41. 6% | 8/sec. | | 56. 3% | 32/sec. | |
| 12. 50% | 2/sec. | | 27. 50% | 16/sec. | | 42. 1% | 4/sec. | | 57. 6% | 16/sec. | |
| 13. 10% | 2/sec. | | 28. 6% | 4/sec. | | 43. 6% | 2/sec. | | 58. 50% | 1/sec. | |
| 14. 1% | 4/sec. | | 29. 1% | 16/sec. | | 44. 50% | 32/sec. | | 59. 3% | 1/sec. | |
| 15. 6% | 8/sec. | | 30. 3% | 8/sec. | | 45. 10% | 4/sec. | | 60. 1% | 1/sec. | |

Table A14. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #5.

| Center Frequency = 500 Hz | | | | | | | | | | | |
|---------------------------|-----|---------|-----|-----|---------|-----|-----|---------|-----|-----|---------|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. | 1% | 32/sec. | 16. | 10% | 1/sec. | 31. | 6% | 6/sec. | 46. | 6% | 32/sec. |
| 2. | 50% | 32/sec. | 17. | 3% | 4/sec. | 32. | 3% | 4/sec. | 47. | 10% | 16/sec. |
| 3. | 10% | 4/sec. | 18. | 1% | 2/sec. | 33. | 6% | 4/sec. | 48. | 50% | 1/sec. |
| 4. | 3% | 16/sec. | 19. | 3% | 16/sec. | 34. | 50% | 32/sec. | 49. | 3% | 1/sec. |
| 5. | 6% | 8/sec. | 20. | 3% | 2/sec. | 35. | 1% | 16/sec. | 50. | 6% | 1/sec. |
| 6. | 6% | 4/sec. | 21. | 50% | 16/sec. | 36. | 6% | 8/sec. | 51. | 50% | 2/sec. |
| 7. | 6% | 32/sec. | 22. | 3% | 32/sec. | 37. | 10% | 4/sec. | 52. | 10% | 8/sec. |
| 8. | 50% | 4/sec. | 23. | 50% | 4/sec. | 38. | 1% | 4/sec. | 53. | 6% | 2/sec. |
| 9. | 10% | 32/sec. | 24. | 1% | 8/sec. | 39. | 3% | 2/sec. | 54. | 50% | 2/sec. |
| 10. | 50% | 16/sec. | 25. | 6% | 1/sec. | 40. | 10% | 2/sec. | 55. | 3% | 1/sec. |
| 11. | 10% | 32/sec. | 26. | 10% | 1/sec. | 41. | 3% | 32/sec. | 56. | 10% | 8/sec. |
| 12. | 1% | 1/sec. | 27. | 1% | 16/sec. | 42. | 6% | 16/sec. | 57. | 6% | 2/sec. |
| 13. | 50% | 8/sec. | 28. | 10% | 16/sec. | 43. | 1% | 8/sec. | 58. | 10% | 2/sec. |
| 14. | 1% | 4/sec. | 29. | 50% | 1/sec. | 44. | 3% | 8/sec. | 59. | 50% | 8/sec. |
| 15. | 1% | 2/sec. | 30. | 1% | 32/sec. | 45. | 3% | 8/sec. | 60. | 1% | 1/sec. |

Table A15. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #1 for test session #6.

| Center Frequency = 250 Hz | | | | | | | | | | | |
|---------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 6% | 1/sec. | | 16. 1% | 2/sec. | | 31. 1% | 16/sec. | | 46. 1% | 1/sec. | |
| 2. 1% | 1/sec. | | 17. 10% | 2/sec. | | 32. 3% | 32/sec. | | 47. 3% | 2/sec. | |
| 3. 1% | 32/sec. | | 18. 6% | 4/sec. | | 33. 10% | 8/sec. | | 48. 3% | 8/sec. | |
| 4. 50% | 2/sec. | | 19. 50% | 16/sec. | | 34. 6% | 8/sec. | | 49. 6% | 32/sec. | |
| 5. 6% | 2/sec. | | 20. 3% | 4/sec. | | 35. 50% | 8/sec. | | 50. 50% | 1/sec. | |
| 6. 10% | 16/sec. | | 21. 10% | 4/sec. | | 36. 3% | 8/sec. | | 51. 1% | 4/sec. | |
| 7. 1% | 2/sec. | | 22. 10% | 8/sec. | | 37. 50% | 16/sec. | | 52. 1% | 16/sec. | |
| 8. 10% | 32/sec. | | 23. 3% | 4/sec. | | 38. 10% | 2/sec. | | 53. 10% | 16/sec. | |
| 9. 50% | 8/sec. | | 24. 50% | 1/sec. | | 39. 6% | 8/sec. | | 54. 6% | 32/sec. | |
| 10. 1% | 32/sec. | | 25. 6% | 16/sec. | | 40. 50% | 32/sec. | | 55. 6% | 4/sec. | |
| 11. 10% | 1/sec. | | 26. 50% | 4/sec. | | 41. 3% | 16/sec. | | 56. 50% | 32/sec. | |
| 12. 1% | 8/sec. | | 27. 3% | 1/sec. | | 42. 10% | 4/sec. | | 57. 3% | 32/sec. | |
| 13. 6% | 2/sec. | | 28. 10% | 32/sec. | | 43. 1 | 8/sec. | | 58. 3% | 1/sec. | |
| 14. 10% | 1/sec. | | 29. 50% | 2/sec. | | 44. 10% | 16/sec. | | 59. 50% | 4/sec. | |
| 15. 6% | 16/sec. | | 30. 1% | 4/sec. | | 45. 3% | 2/sec. | | 60. 6% | 1/sec. | |

Table A16. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #1.

| Center Frequency = 1000 Hz | | | | | | | | | | | |
|----------------------------|----|---------|---------|----|---------|---------|----|---------|---------|----|---------|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 50% | | 2/sec. | 16. 3% | | 1/sec. | 31. 3% | | 1/sec. | 46. 50% | | 1/sec. |
| 2. 10% | | 32/sec. | 17. 50% | | 2/sec. | 32. 3% | | 2/sec. | 47. 6% | | 32/sec. |
| 3. 6% | | 2/sec. | 18. 3% | | 32/sec. | 33. 50% | | 32/sec. | 48. 1% | | 8/sec. |
| 4. 6% | | 1/sec. | 19. 1% | | 32/sec. | 34. 6% | | 32/sec. | 49. 1% | | 16/sec. |
| 5. 1% | | 4/sec. | 20. 10% | | 2/sec. | 35. 3% | | 16/sec. | 50. 50% | | 8/sec. |
| 6. 1% | | 2/sec. | 21. 3% | | 8/sec. | 36. 10% | | 32/sec. | 51. 1% | | 32/sec. |
| 7. 3% | | 16/sec. | 22. 6% | | 4/sec. | 37. 50% | | 1/sec. | 52. 1% | | 16/sec. |
| 8. 6% | | 16/sec. | 23. 3% | | 4/sec. | 38. 1% | | 1/sec. | 53. 3% | | 2/sec. |
| 9. 6% | | 2/sec. | 24. 10% | | 16/sec. | 39. 6% | | 8/sec. | 54. 10% | | 1/sec. |
| 10. 10% | | 2/sec. | 25. 50% | | 4/sec. | 40. 6% | | 16/sec. | 55. 1% | | 2/sec. |
| 11. 10% | | 8/sec. | 26. 10% | | 4/sec. | 41. 50% | | 32/sec. | 56. 10% | | 4/sec. |
| 12. 6% | | 8/sec. | 27. 3% | | 4/sec. | 42. 10% | | 1/sec. | 57. 50% | | 4/sec. |
| 13. 6% | | 4/sec. | 28. 1% | | 4/sec. | 43. 50% | | 16/sec. | 58. 50% | | 8/sec. |
| 14. 50% | | 16/sec. | 29. 10% | | 16/sec. | 44. 1% | | 8/sec. | 59. 3% | | 32/sec. |
| 15. 3% | | 8/sec. | 30. 1% | | 1/sec. | 45. 6% | | 1/sec. | 60. 10% | | 8/sec. |

Table A17. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #2.

| Center Frequency = 2000 Hz | | | | | | | | | | | |
|----------------------------|-----------------|-----------------|-----------------|----|----|----|----|----|----|----|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% 16/sec. | 16. 10% 32/sec. | 31. 50% 16/sec. | 46. 1% 32/sec. | | | | | | | | |
| 2. 1% 2/sec. | 17. 3% 16/sec. | 32. 1% 32/sec. | 47. 10% 32/sec. | | | | | | | | |
| 3. 3% 1/sec. | 18. 10% 4/sec. | 33. 6% 1/sec. | 48. 6% 32/sec. | | | | | | | | |
| 4. 6% 32/sec. | 19. 6% 4/sec. | 34. 1% 2/sec. | 49. 3% 2/sec. | | | | | | | | |
| 5. 10% 16/sec. | 20. 3% 16/sec. | 35. 10% 1/sec. | 50. 50% 32/sec. | | | | | | | | |
| 6. 10% 8/sec. | 21. 1% 8/sec. | 36. 6% 16/sec. | 51. 10% 16/sec. | | | | | | | | |
| 7. 1% 1/sec. | 22. 10% 8/sec. | 37. 3% 4/sec. | 52. 50% 4/sec. | | | | | | | | |
| 8. 50% 1/sec. | 23. 50% 8/sec. | 38. 50% 4/sec. | 53. 50% 8/sec. | | | | | | | | |
| 9. 10% 1/sec. | 24. 3% 4/sec. | 39. 1% 8/sec. | 54. 3% 2/sec. | | | | | | | | |
| 10. 6% 1/sec. | 25. 3% 32/sec. | 40. 6% 2/sec. | 55. 3% 8/sec. | | | | | | | | |
| 11. 50% 2/sec. | 26. 10% 2/sec. | 41. 6% 8/sec. | 56. 3% 2/sec. | | | | | | | | |
| 12. 50% 2/sec. | 27. 50% 16/sec. | 42. 1% 4/sec. | 57. 6% 16/sec. | | | | | | | | |
| 13. 10% 2/sec. | 28. 6% 4/sec. | 53. 6% 2/sec. | 58. 50% 1/sec. | | | | | | | | |
| 14. 1% 4/sec. | 29. 1% 16/sec. | 54. 50% 32/sec. | 59. 3% 1/sec. | | | | | | | | |
| 15. 6% 8/sec. | 30. 3% 8/sec. | 55. 10% 4/sec. | 60. 1% 1/sec. | | | | | | | | |

Table A18. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #3.

| Center Frequency = 4000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 6% | 1/sec. | | 16. 1% | 1/sec. | | 31. 1% | 32/sec. | | 46. 10% | 4/sec. | |
| 2. 10% | 8/sec. | | 17. 6% | 16/sec. | | 32. 6% | 4/sec. | | 47. 50% | 16/sec. | |
| 3. 10% | 8/sec. | | 18. 1% | 2/sec. | | 33. 6% | 32/sec. | | 48. 10% | 1/sec. | |
| 4. 3% | 2/sec. | | 19. 1% | 1/sec. | | 34. 3% | 8/sec. | | 49. 50% | 2/sec. | |
| 5. 50% | 8/sec. | | 20. 6% | 1/sec. | | 35. 1% | 4/sec. | | 50. 1% | 8/sec. | |
| 6. 6% | 2/sec. | | 21. 3% | 8/sec. | | 36. 6% | 32/sec. | | 51. 3% | 16/sec. | |
| 7. 1% | 16/sec. | | 22. 50% | 8/sec. | | 37. 1% | 8/sec. | | 52. 50% | 4/sec. | |
| 8. 1% | 1/sec. | | 23. 3% | 1/sec. | | 38. 3% | 4/sec. | | 53. 50% | 16/sec. | |
| 9. 6% | 8/sec. | | 24. 3% | 4/sec. | | 39. 6% | 2/sec. | | 54. 1% | 16/sec. | |
| 10. 1% | 32/sec. | | 25. 10% | 4/sec. | | 40. 10% | 1/sec. | | 55. 1% | 4/sec. | |
| 11. 10% | 32/sec. | | 26. 3% | 32/sec. | | 41. 10% | 2/sec. | | 56. 3% | 1/sec. | |
| 12. 6% | 8/sec. | | 27. 3% | 16/sec. | | 42. 50% | 1/sec. | | 57. 50% | 2/sec. | |
| 13. 10% | 16/sec. | | 28. 3% | 2/sec. | | 43. 10% | 32/sec. | | 58. 6% | 16/sec. | |
| 14. 50% | 32/sec. | | 29. 6% | 4/sec. | | 44. 10% | 16/sec. | | 59. 50% | 1/sec. | |
| 15. 50% | 4/sec. | | 30. 50% | 32/sec. | | 45. 3% | 32/sec. | | 60. 10% | 2/sec. | |

Table A19. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #4.

| Center Frequency = 8000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 6% | 1/sec. | | 16. 1% | 2/sec. | | 31. 1% | 16/sec. | | 46. 1% | 1/sec. | |
| 2. 1% | 1/sec. | | 17. 10% | 2/sec. | | 32. 3% | 32/sec. | | 47. 3% | 2/sec. | |
| 3. 1% | 32/sec. | | 18. 6% | 4/sec. | | 33. 10% | 8/sec. | | 48. 3% | 8/sec. | |
| 4. 50% | 2/sec. | | 19. 50% | 16/sec. | | 34. 6% | 8/sec. | | 49. 6% | 32/sec. | |
| 5. 6% | 2/sec. | | 20. 3% | 4/sec. | | 35. 50% | 8/sec. | | 50. 50% | 1/sec. | |
| 6. 10% | 16/sec. | | 21. 10% | 4/sec. | | 36. 3% | 8/sec. | | 51. 1% | 4/sec. | |
| 7. 1% | 2/sec. | | 22. 10% | 8/sec. | | 37. 50% | 16/sec. | | 52. 1% | 16/sec. | |
| 8. 10% | 32/sec. | | 23. 3% | 4/sec. | | 38. 10% | 2/sec. | | 53. 10% | 16/sec. | |
| 9. 50% | 8/sec. | | 24. 50% | 1/sec. | | 39. 3% | 16/sec. | | 54. 6% | 32/sec. | |
| 10. 1% | 32/sec. | | 25. 6% | 16/sec. | | 40. 6% | 8/sec. | | 55. 6% | 4/sec. | |
| 11. 10% | 1/sec. | | 26. 50% | 4/sec. | | 41. 50% | 32/sec. | | 56. 50% | 32/sec. | |
| 12. 1% | 8/sec. | | 27. 3% | 1/sec. | | 42. 10% | 4/sec. | | 57. 3% | 32/sec. | |
| 13. 6% | 2/sec. | | 28. 10% | 32/sec. | | 43. 1% | 8/sec. | | 58. 3% | 1/sec. | |
| 14. 10% | 1/sec. | | 29. 50% | 2/sec. | | 44. 3% | 16/sec. | | 59. 50% | 4/sec. | |
| 15. 6% | 16/sec. | | 30. 1% | 4/sec. | | 45. 3% | 2/sec. | | 60. 6% | 1/sec. | |

Table A20. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #5.

| Center Frequency = 500 Hz | | | | | | | | | | | |
|---------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 4/sec. | | 16. 3% | 16/sec. | | 31. 1% | 1/sec. | | 46. 50% | 32/sec. | |
| 2. 6% | 32/sec. | | 17. 6% | 2/sec. | | 32. 6% | 4/sec. | | 47. 1% | 32/sec. | |
| 3. 3% | 1/sec. | | 18. 3% | 1/sec. | | 33. 1% | 16/sec. | | 48. 1% | 1/sec. | |
| 4. 50% | 4/sec. | | 19. 50% | 8/sec. | | 34. 1% | 8/sec. | | 49. 50% | 8/sec. | |
| 5. 1% | 2/sec. | | 20. 3% | 32/sec. | | 35. 6% | 8/sec. | | 50. 6% | 1/sec. | |
| 6. 10% | 32/sec. | | 21. 3% | 8/sec. | | 36. 3% | 32/sec. | | 51. 6% | 32/sec. | |
| 7. 6% | 2/sec. | | 22. 50% | 32/sec. | | 37. 10% | 4/sec. | | 52. 10% | 8/sec. | |
| 8. 10% | 1/sec. | | 23. 50% | 4/sec. | | 38. 1% | 8/sec. | | 53. 10% | 16/sec. | |
| 9. 6% | 1/sec. | | 24. 10% | 8/sec. | | 39. 10% | 16/sec. | | 54. 3% | 8/sec. | |
| 10. 3% | 16/sec. | | 25. 50% | 2/sec. | | 40. 3% | 4/sec. | | 55. 50% | 1/sec. | |
| 11. 6% | 16/sec. | | 26. 10% | 2/sec. | | 41. 50% | 16/sec. | | 56. 3% | 2/sec. | |
| 12. 50% | 1/sec. | | 27. 1% | 2/sec. | | 42. 6% | 16/sec. | | 57. 1% | 16/sec. | |
| 13. 6% | 8/sec. | | 28. 3% | 2/sec. | | 43. 50% | 16/sec. | | 58. 1% | 4/sec. | |
| 14. 50% | 2/sec. | | 29. 6% | 4/sec. | | 44. 3% | 4/sec. | | 59. 10% | 4/sec. | |
| 15. 10% | 32/sec. | | 30. 1% | 32/sec. | | 45. 10% | 2/sec. | | 60. 10% | 2/sec. | |

Table A21. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #2 for test session #6.

| Center Frequency = 250 Hz | | | | | | | | | | | |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|----|----|----|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 4/sec. | 16. 3% | 16/sec. | 31. 1% | 1/sec. | 46. 50% | 32/sec. | | | | |
| 2. 6% | 32/sec. | 17. 6% | 2/sec. | 32. 6% | 4/sec. | 47. 1% | 32/sec. | | | | |
| 3. 3% | 1/sec. | 18. 3% | 1/sec. | 33. 1% | 16/sec. | 48. 1% | 1/sec. | | | | |
| 4. 50% | 4/sec. | 19. 50% | 8/sec. | 34. 1% | 8/sec. | 49. 50% | 8/sec. | | | | |
| 5. 1% | 2/sec. | 20. 3% | 32/sec. | 35. 6% | 8/sec. | 50. 6% | 1/sec. | | | | |
| 6. 10% | 32/sec. | 21. 3% | 8/sec. | 36. 3% | 32/sec. | 51. 6% | 32/sec. | | | | |
| 7. 6% | 2/sec. | 22. 50% | 32/sec. | 37. 10% | 4/sec. | 52. 10% | 8/sec. | | | | |
| 8. 10% | 1/sec. | 23. 50% | 4/sec. | 38. 1% | 8/sec. | 53. 10% | 16/sec. | | | | |
| 9. 6% | 1/sec. | 24. 10% | 8/sec. | 39. 10% | 16/sec. | 54. 3% | 8/sec. | | | | |
| 10. 3% | 16/sec. | 25. 50% | 2/sec. | 40. 3% | 4/sec. | 55. 50% | 1/sec. | | | | |
| 11. 6% | 16/sec. | 26. 10% | 1/sec. | 41. 50% | 16/sec. | 56. 3% | 2/sec. | | | | |
| 12. 50% | 1/sec. | 27. 1% | 2/sec. | 42. 6% | 16/sec. | 57. 1% | 16/sec. | | | | |
| 13. 6% | 8/sec. | 28. 3% | 2/sec. | 43. 50% | 16/sec. | 58. 1% | 4/sec. | | | | |
| 14. 50% | 2/sec. | 29. 6% | 4/sec. | 44. 3% | 4/sec. | 59. 10% | 4/sec. | | | | |
| 15. 10% | 32/sec. | 30. 1% | 32/sec. | 45. 10% | 2/sec. | 60. 10% | 2/sec. | | | | |

Table A22. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #1.

| Center Frequency = 1000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 16/sec. | | 16. 10% | 32/sec. | | 31. 50% | 16/sec. | | 46. 1% | 32/sec. | |
| 2. 1% | 2/sec. | | 17. 3% | 16/sec. | | 32. 1% | 32/sec. | | 47. 10% | 32/sec. | |
| 3. 3% | 1/sec. | | 18. 10% | 4/sec. | | 33. 6% | 1/sec. | | 48. 6% | 32/sec. | |
| 4. 6% | 32/sec. | | 19. 6% | 4/sec. | | 34. 1% | 2/sec. | | 49. 3% | 2/sec. | |
| 5. 10% | 16/sec. | | 20. 3% | 16/sec. | | 35. 10% | 1/sec. | | 50. 50% | 32/sec. | |
| 6. 10% | 8/sec. | | 21. 1% | 8/sec. | | 36. 6% | 16/sec. | | 51. 10% | 16/sec. | |
| 7. 1% | 1/sec. | | 22. 10% | 8/sec. | | 37. 3% | 4/sec. | | 52. 50% | 4/sec. | |
| 8. 50% | 1/sec. | | 23. 50% | 8/sec. | | 38. 50% | 4/sec. | | 53. 50% | 8/sec. | |
| 9. 10% | 1/sec. | | 24. 3% | 4/sec. | | 39. 1% | 8/sec. | | 54. 3% | 2/sec. | |
| 10. 6% | 1/sec. | | 25. 3% | 32/sec. | | 40. 6% | 2/sec. | | 55. 3% | 8/sec. | |
| 11. 50% | 2/sec. | | 26. 10% | 2/sec. | | 41. 6% | 8/sec. | | 56. 3% | 32/sec. | |
| 12. 50% | 2/sec. | | 27. 50% | 16/sec. | | 42. 1% | 4/sec. | | 57. 6% | 16/sec. | |
| 13. 10% | 2/sec. | | 28. 6% | 4/sec. | | 43. 6% | 2/sec. | | 58. 50% | 1/sec. | |
| 14. 1% | 4/sec. | | 29. 1% | 16/sec. | | 44. 50% | 32/sec. | | 59. 3% | 1/sec. | |
| 15. 6% | 8/sec. | | 30. 3% | 8/sec. | | 45. 10% | 4/sec. | | 60. 1% | 1/sec. | |

Table A23. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #2.

| Center Frequency = 2000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 6% | 1/sec. | | 16. 1% | 2/sec. | | 31. 1% | 16/sec. | | 46. 1% | 1/sec. | |
| 2. 1% | 1/sec. | | 17. 10% | 2/sec. | | 32. 3% | 32/sec. | | 47. 3% | 2/sec. | |
| 3. 1% | 32/sec. | | 18. 6% | 4/sec. | | 33. 10% | 8/sec. | | 48. 3% | 8/sec. | |
| 4. 50% | 2/sec. | | 19. 50% | 16/sec. | | 34. 6% | 8/sec. | | 49. 6% | 32/sec. | |
| 5. 6% | 2/sec. | | 20. 3% | 4/sec. | | 35. 50% | 8/sec. | | 50. 50% | 1/sec. | |
| 6. 10% | 16/sec. | | 21. 10% | 4/sec. | | 36. 3% | 8/sec. | | 51. 1% | 4/sec. | |
| 7. 1% | 2/sec. | | 22. 10% | 8/sec. | | 37. 50% | 16/sec. | | 52. 1% | 16/sec. | |
| 8. 10% | 32/sec. | | 23. 3% | 4/sec. | | 38. 10% | 2/sec. | | 53. 10% | 16/sec. | |
| 9. 50% | 8/sec. | | 24. 50% | 1/sec. | | 39. 3% | 16/sec. | | 54. 6% | 32/sec. | |
| 10. 1% | 32/sec. | | 25. 6% | 16/sec. | | 40. 6% | 8/sec. | | 55. 6% | 4/sec. | |
| 11. 10% | 1/sec. | | 26. 50% | 4/sec. | | 41. 50% | 32/sec. | | 56. 50% | 32/sec. | |
| 12. 1% | 8/sec. | | 27. 3% | 1/sec. | | 42. 10% | 4/sec. | | 57. 3% | 32/sec. | |
| 13. 6% | 2/sec. | | 28. 10% | 32/sec. | | 43. 1% | 8/sec. | | 58. 3% | 1/sec. | |
| 14. 10% | 1/sec. | | 29. 50% | 2/sec. | | 44. 3% | 16/sec. | | 59. 50% | 4/sec. | |
| 15. 6% | 16/sec. | | 30. 1% | 4/sec. | | 45. 3% | 2/sec. | | 60. 6% | 1/sec. | |

Table A24. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #3.

| Center Frequency = 4000 Hz | | | | | | | | | | | |
|----------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 50% | 2/sec. | | 16. 3% | 1/sec. | | 31. 3% | 1/sec. | | 46. 50% | 1/sec. | |
| 2. 10% | 32/sec. | | 17. 50% | 2/sec. | | 32. 3% | 2/sec. | | 47. 6% | 32/sec. | |
| 3. 6% | 2/sec. | | 18. 3% | 32/sec. | | 33. 50% | 32/sec. | | 48. 1% | 8/sec. | |
| 4. 6% | 1/sec. | | 19. 1% | 32/sec. | | 34. 6% | 32/sec. | | 49. 1% | 16/sec. | |
| 5. 1% | 4/sec. | | 20. 10% | 2/sec. | | 35. 3% | 16/sec. | | 50. 50% | 8/sec. | |
| 6. 1% | 2/sec. | | 21. 3% | 8/sec. | | 36. 10% | 32/sec. | | 51. 1% | 32/sec. | |
| 7. 3% | 16/sec. | | 22. 6% | 4/sec. | | 37. 50% | 1/sec. | | 52. 1% | 16/sec. | |
| 8. 6% | 16/sec. | | 23. 3% | 4/sec. | | 38. 1% | 1/sec. | | 53. 3% | 2/sec. | |
| 9. 6% | 2/sec. | | 24. 10% | 16/sec. | | 39. 6% | 8/sec. | | 54. 10% | 1/sec. | |
| 10. 10% | 2/sec. | | 25. 50% | 4/sec. | | 40. 6% | 16/sec. | | 55. 1% | 2/sec. | |
| 11. 10% | 8/sec. | | 26. 10% | 4/sec. | | 41. 50% | 32/sec. | | 56. 10% | 4/sec. | |
| 12. 6% | 8/sec. | | 27. 3% | 4/sec. | | 42. 10% | 1/sec. | | 57. 50% | 4/sec. | |
| 13. 6% | 4/sec. | | 28. 1% | 4/sec. | | 43. 50% | 16/sec. | | 58. 50% | 8/sec. | |
| 14. 50% | 16/sec. | | 29. 10% | 16/sec. | | 44. 1% | 8/sec. | | 59. 3% | 32/sec. | |
| 15. 3% | 8/sec. | | 30. 1% | 1/sec. | | 45. 6% | 1/sec. | | 60. 10% | 8/sec. | |

Table A25. Randomised presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #4.

| Center Frequency = 8000 Hz | | | | | | | | | | | |
|----------------------------|-----------------|-----------------|-----------------|----|----|----|----|----|----|----|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% 32/sec. | 16. 10% 1/sec. | 31. 6% 16/sec. | 46. 6% 32/sec. | | | | | | | | |
| 2. 50% 32/sec. | 17. 3% 4/sec. | 32. 3% 4/sec. | 47. 10% 16/sec. | | | | | | | | |
| 3. 10% 4/sec. | 18. 1% 2/sec. | 33. 6% 4/sec. | 48. 50% 1/sec. | | | | | | | | |
| 4. 3% 16/sec. | 19. 3% 16/sec. | 34. 50% 32/sec. | 49. 3% 1/sec. | | | | | | | | |
| 5. 6% 8/sec. | 20. 3% 2/sec. | 35. 1% 16/sec. | 50. 6% 1/sec. | | | | | | | | |
| 6. 6% 4/sec. | 21. 50% 16/sec. | 36. 6% 8/sec. | 51. 50% 2/sec. | | | | | | | | |
| 7. 6% 32/sec. | 22. 3% 32/sec. | 37. 10% 4/sec. | 52. 10% 8/sec. | | | | | | | | |
| 8. 50% 4/sec. | 23. 50% 4/sec. | 38. 1% 4/sec. | 53. 6% 2/sec. | | | | | | | | |
| 9. 10% 32/sec. | 24. 1% 8/sec. | 39. 3% 2/sec. | 54. 50% 2/sec. | | | | | | | | |
| 10. 50% 16/sec. | 25. 6% 1/sec. | 40. 10% 2/sec. | 55. 3% 1/sec. | | | | | | | | |
| 11. 10% 32/sec. | 26. 10% 1/sec. | 41. 3% 32/sec. | 56. 10% 8/sec. | | | | | | | | |
| 12. 1% 1/sec. | 27. 1% 16/sec. | 42. 6% 16/sec. | 57. 6% 2/sec. | | | | | | | | |
| 13. 50% 8/sec. | 28. 10% 16/sec. | 43. 1% 8/sec. | 58. 10% 2/sec. | | | | | | | | |
| 14. 1% 4/sec. | 29. 50% 1/sec. | 44. 3% 8/sec. | 59. 50% 8/sec. | | | | | | | | |
| 15. 1% 2/sec. | 30. 1% 32/sec. | 45. 3% 8/sec. | 60. 1% 1/sec. | | | | | | | | |

Table A26. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #5.

| Center Frequency = 500 Hz | | | | | | | | | | | |
|---------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 6% | 1/sec. | | 16. 1% | 1/sec. | | 31. 1% | 32/sec. | | 46. 10% | 4/sec. | |
| 2. 10% | 8/sec. | | 17. 6% | 16/sec. | | 32. 6% | 4/sec. | | 47. 50% | 16/sec. | |
| 3. 10% | 8/sec. | | 18. 1% | 2/sec. | | 33. 6% | 32/sec. | | 48. 10% | 1/sec. | |
| 4. 3% | 2/sec. | | 19. 1% | 2/sec. | | 34. 3% | 8/sec. | | 49. 50% | 2/sec. | |
| 5. 50% | 8/sec. | | 20. 6% | 1/sec. | | 35. 1% | 4/sec. | | 50. 1% | 8/sec. | |
| 6. 6% | 2/sec. | | 21. 3% | 8/sec. | | 36. 6% | 32/sec. | | 51. 3% | 16/sec. | |
| 7. 1% | 16/sec. | | 22. 50% | 8/sec. | | 37. 1% | 8/sec. | | 52. 50% | 4/sec. | |
| 8. 1% | 1/sec. | | 23. 3% | 1/sec. | | 38. 3% | 4/sec. | | 53. 50% | 16/sec. | |
| 9. 6% | 8/sec. | | 24. 3% | 4/sec. | | 39. 6% | 2/sec. | | 54. 1% | 16/sec. | |
| 10. 1% | 32/sec. | | 25. 10% | 4/sec. | | 40. 10% | 1/sec. | | 55. 1% | 4/sec. | |
| 11. 10% | 32/sec. | | 26. 3% | 32/sec. | | 41. 10% | 2/sec. | | 56. 3% | 1/sec. | |
| 12. 6% | 8/sec. | | 27. 3% | 16/sec. | | 42. 50% | 1/sec. | | 57. 50% | 2/sec. | |
| 13. 10% | 16/sec. | | 28. 3% | 2/sec. | | 43. 10% | 32/sec. | | 58. 6% | 16/sec. | |
| 14. 50% | 32/sec. | | 29. 6% | 4/sec. | | 44. 10% | 16/sec. | | 59. 50% | 1/sec. | |
| 15. 50% | 4/sec. | | 30. 50% | 32/sec. | | 45. 3% | 32/sec. | | 60. 10% | 2/sec. | |

Table A27. Randomized presentation order (PO) for the various combinations of warble-tone frequency deviations (FD) and modulation rates (MR) for subject #3 for test session #6.

| Center Frequency = 250 Hz | | | | | | | | | | | |
|---------------------------|---------|----|---------|---------|----|---------|---------|----|---------|---------|----|
| PO | FD | MR | PO | FD | MR | PO | FD | MR | PO | FD | MR |
| 1. 1% | 4/sec. | | 16. 3% | 16/sec. | | 31. 1% | 1/sec. | | 46. 50% | 32/sec. | |
| 2. 6% | 32/sec. | | 17. 6% | 2/sec. | | 32. 6% | 4/sec. | | 47. 1% | 32/sec. | |
| 3. 3% | 1/sec. | | 18. 3% | 1/sec. | | 33. 1% | 16/sec. | | 48. 1% | 1/sec. | |
| 4. 50% | 4/sec. | | 19. 50% | 8/sec. | | 34. 1% | 8/sec. | | 49. 50% | 8/sec. | |
| 5. 1% | 2/sec. | | 20. 3% | 32/sec. | | 35. 6% | 8/sec. | | 50. 6% | 1/sec. | |
| 6. 10% | 32/sec. | | 21. 3% | 8/sec. | | 36. 3% | 32/sec. | | 51. 6% | 32/sec. | |
| 7. 6% | 2/sec. | | 22. 50% | 32/sec. | | 37. 10% | 4/sec. | | 52. 10% | 8/sec. | |
| 8. 10% | 1/sec. | | 23. 50% | 4/sec. | | 38. 1% | 8/sec. | | 53. 10% | 16/sec. | |
| 9. 6% | 1/sec. | | 24. 10% | 8/sec. | | 39. 10% | 16/sec. | | 54. 3% | 8/sec. | |
| 10. 3% | 16/sec. | | 25. 50% | 2/sec. | | 40. 3% | 4/sec. | | 55. 50% | 1/sec. | |
| 11. 6% | 16/sec. | | 26. 10% | 1/sec. | | 41. 50% | 16/sec. | | 56. 3% | 2/sec. | |
| 12. 50% | 1/sec. | | 27. 1% | 2/sec. | | 42. 6% | 16/sec. | | 57. 1% | 16/sec. | |
| 13. 6% | 8/sec. | | 28. 3% | 2/sec. | | 43. 50% | 16/sec. | | 58. 1% | 4/sec. | |
| 14. 50% | 2/sec. | | 29. 6% | 4/sec. | | 44. 3% | 4/sec. | | 59. 10% | 4/sec. | |
| 15. 10% | 32/sec. | | 30. 1% | 32/sec. | | 45. 10% | 2/sec. | | 60. 10% | 2/sec. | |

APPENDIX J

**FREQUENCY DEVIATIONS FOR EACH TEST FREQUENCY (IN BOTH PERCENT AND HZ)
ALONG WITH READINGS REQUIRED ON THE INSTRUMENTATION UTILIZED
TO PRODUCE AND MEASURE THE WARBLE-TONE STIMULI**

**FREQUENCY DEVIATIONS FOR EACH TEST FREQUENCY (IN BOTH PERCENT AND HZ)
ALONG WITH READINGS REQUIRED ON THE INSTRUMENTATION UTILIZED
TO PRODUCE AND MEASURE THE WARBLE-TONE STIMULI**

Table A28. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 250 Hz | | | | | |
|----------------------------------|------|------|------|------|------|
| Percent Frequency Deviation | ±1% | ±3% | ±6% | ±10% | ±50% |
| Frequency Deviation in Hz | 5 | 15 | 30 | 50 | 250 |
| Instrument Dial Setting Required | | | | | |
| FD | ±100 | ±100 | ±100 | ±100 | ±250 |
| VS | 1 | 1 | 3 | 3 | 10 |
| V | 0.25 | 0.5 | 1.1 | 1.6 | 4.0 |
| H/D | 10 | 10 | 10 | 10 | 50 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

Table A29. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 500 Hz | | | | | |
|----------------------------------|-----------|-----------|-----------|------------|------------|
| Percent Frequency Deviation | $\pm 1\%$ | $\pm 3\%$ | $\pm 6\%$ | $\pm 10\%$ | $\pm 50\%$ |
| Frequency Deviation in Hz | 10 | 30 | 60 | 100 | 500 |
| Instrument Dial Setting Required | | | | | |
| FD | ± 100 | ± 100 | ± 100 | ± 100 | ± 400 |
| VS | 1 | 3 | 3 | 3 | 20 |
| V | 0.4 | 1.0 | 1.9 | 2.8 | 4.0 |
| H/D | 10 | 10 | 10 | 20 | 100 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

Table A30. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 1000 Hz | | | | | |
|----------------------------------|-----------|-----------|-----------|------------|------------|
| Percent Frequency Deviation | $\pm 1\%$ | $\pm 3\%$ | $\pm 6\%$ | $\pm 10\%$ | $\pm 50\%$ |
| Frequency Deviation in Hz | 20 | 60 | 120 | 200 | 1000 |
| Instrument Dial Setting Required | | | | | |
| FD | ± 100 | ± 100 | ± 100 | ± 160 | ± 630 |
| VS | 1 | 3 | 10 | 10 | 10 |
| V | 0.78 | 1.7 | 3.4 | 4.2 | 4.2 |
| H/D | 10 | 50 | 50 | 50 | 100 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

Table A31. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 2000 Hz | | | | | |
|----------------------------------|-----------|-----------|-----------|------------|------------|
| Percent Frequency Deviation | $\pm 1\%$ | $\pm 3\%$ | $\pm 6\%$ | $\pm 10\%$ | $\pm 50\%$ |
| Frequency Deviation in Hz | 40 | 120 | 240 | 400 | 2000 |
| Instrument Dial Setting Required | | | | | |
| FD | ± 100 | ± 100 | ± 160 | ± 400 | ± 1000 |
| VS | 3 | 10 | 10 | 10 | 10 |
| V | 1.3 | 3.4 | 4.8 | 3.2 | 4.0 |
| H/D | 20 | 50 | 50 | 100 | 200 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

Table A32. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 4000 Hz | | | | | |
|----------------------------------|-----------|-----------|-----------|------------|------------|
| Percent Frequency Deviation | $\pm 1\%$ | $\pm 3\%$ | $\pm 6\%$ | $\pm 10\%$ | $\pm 50\%$ |
| Frequency Deviation in Hz | 80 | 240 | 480 | 800 | 4000 |
| Instrument Dial Setting Required | | | | | |
| FD | ± 100 | ± 250 | ± 400 | ± 630 | ± 1500 |
| VS | 3 | 10 | 10 | 10 | 10 |
| V | 2.4 | 3.7 | 3.8 | 3.4 | 3.6 |
| H/D | 20 | 50 | 100 | 100 | 500 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

Table A33. The FREQUENCY DEVIATION (FD) setting required on the beat-frequency oscillator, along with the VOLT SCALE (VS) and OUTPUT VOLTAGE (V) on the function generator, and the Hz/DIV (H/D) setting of the storage scope spectrum analyzer to produce and measure the warble-tone frequency deviations given.*

| Center Frequency = 8000 Hz | | | | | |
|----------------------------------|-----------|-----------|-----------|------------|------------|
| Percent Frequency Deviation | $\pm 1\%$ | $\pm 3\%$ | $\pm 6\%$ | $\pm 10\%$ | $\pm 50\%$ |
| Frequency Deviation in Hz | 160 | 480 | 960 | 1600 | 8000 |
| Instrument Dial Setting Required | | | | | |
| FD | ± 400 | ± 400 | ± 960 | ± 1000 | ± 2500 |
| VS | 3 | 10 | 10 | 10 | 10 |
| V | 1.4 | 4.1 | 4.4 | 3.8 | 8.6 |
| H/D | 50 | 100 | 200 | 500 | 1000 |

*The modulation rates used in this study had no effect on any of the measured frequency deviations and consequently are not shown in the table.

APPENDIX K

**AVERAGE HEARING THRESHOLD LEVEL AND SOUND PRESSURE LEVEL THRESHOLDS
FOR EACH SUBJECT UNDER EACH OF THE WARBLE-TONE COMBINATIONS
FOR EACH FREQUENCY**

Table A35. Average (repeated measure) Hearing Threshold Level (HTL) and Sound Pressure Level (SPL) thresholds for each subject under each of the warble-tone combinations for 500 Hz.

| Center Frequency = 500 Hz | | | | | | | | | | | | | | | | | | | |
|---------------------------|-----|---------------------|-------|------|-----------|-------|------|-----------|-------|------|------------|-------|------|------------|-------|------|---------|---|---|
| | | Frequency Deviation | | | | | | | | | | | | | | | | | |
| | | $\pm 1\%$ | | | $\pm 3\%$ | | | $\pm 6\%$ | | | $\pm 10\%$ | | | $\pm 50\%$ | | | | | |
| | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1/sec. | HTL | -13.0 | -11.5 | -3.0 | -15.5 | -12.0 | -5.0 | -15.5 | -13.5 | -2.0 | -14.0 | -9.5 | -3.0 | -15.5 | -11.0 | -1.5 | | | |
| | SPL | 8.5 | 10.0 | 18.5 | 6.0 | 9.5 | 16.5 | 6.0 | 8.0 | 19.5 | 7.5 | 12.0 | 18.5 | 6.0 | 10.5 | 20.0 | | | |
| 2/sec. | HTL | -10.0 | -11.5 | -2.5 | -11.5 | -11.0 | -2.5 | -14.5 | -11.5 | -2.5 | -15.5 | -10.0 | -3.5 | -14.0 | -11.0 | -1.5 | | | |
| | SPL | 11.5 | 10.0 | 19.0 | 10.0 | 10.5 | 19.0 | 7.0 | 10.0 | 19.0 | 6.0 | 11.5 | 18.0 | 7.5 | 10.5 | 20.0 | | | |
| 4/sec. | HTL | -11.5 | -12.5 | -3.5 | -13.0 | -12.5 | -3.5 | -10.5 | -11.0 | -5.0 | -9.0 | -10.5 | -7.0 | -7.0 | -10.0 | -1.0 | | | |
| | SPL | 10.0 | 9.0 | 18.0 | 8.5 | 9.0 | 18.0 | 11.0 | 10.5 | 16.5 | 12.5 | 11.0 | 14.5 | 14.5 | 11.5 | 20.5 | | | |
| 8/sec. | HTL | -13.0 | -12.5 | -4.0 | -14.0 | -11.5 | -2.5 | -9.5 | -10.5 | -2.0 | -13.5 | -9.0 | 0.0 | -9.0 | -11.5 | -0.5 | | | |
| | SPL | 8.5 | 9.0 | 17.5 | 7.5 | 10.0 | 19.0 | 12.0 | 11.0 | 19.5 | 8.0 | 12.5 | 21.5 | 12.5 | 10.0 | 21.0 | | | |
| 16/sec. | HTL | -14.5 | -11.0 | -2.0 | -8.0 | -12.5 | -2.5 | -12.5 | -10.5 | -4.0 | -11.0 | -10.5 | -3.0 | -5.0 | -8.0 | -0.5 | | | |
| | SPL | 7.0 | 10.5 | 19.5 | 13.5 | 9.0 | 19.0 | 9.0 | 11.0 | 17.5 | 10.5 | 11.0 | 18.5 | 16.5 | 13.5 | 21.0 | | | |
| 32/sec. | HTL | -9.5 | -12.5 | -4.5 | -15.0 | -12.0 | -4.0 | -7.5 | -12.0 | -1.5 | -5.5 | -10.5 | -3.5 | -6.0 | -8.5 | 0.0 | | | |
| | SPL | 12.0 | 9.0 | 17.0 | 6.5 | 9.5 | 17.5 | 14.0 | 9.5 | 20.0 | 16.0 | 11.0 | 18.0 | 15.5 | 13.0 | 21.5 | | | |

Modulation Rate

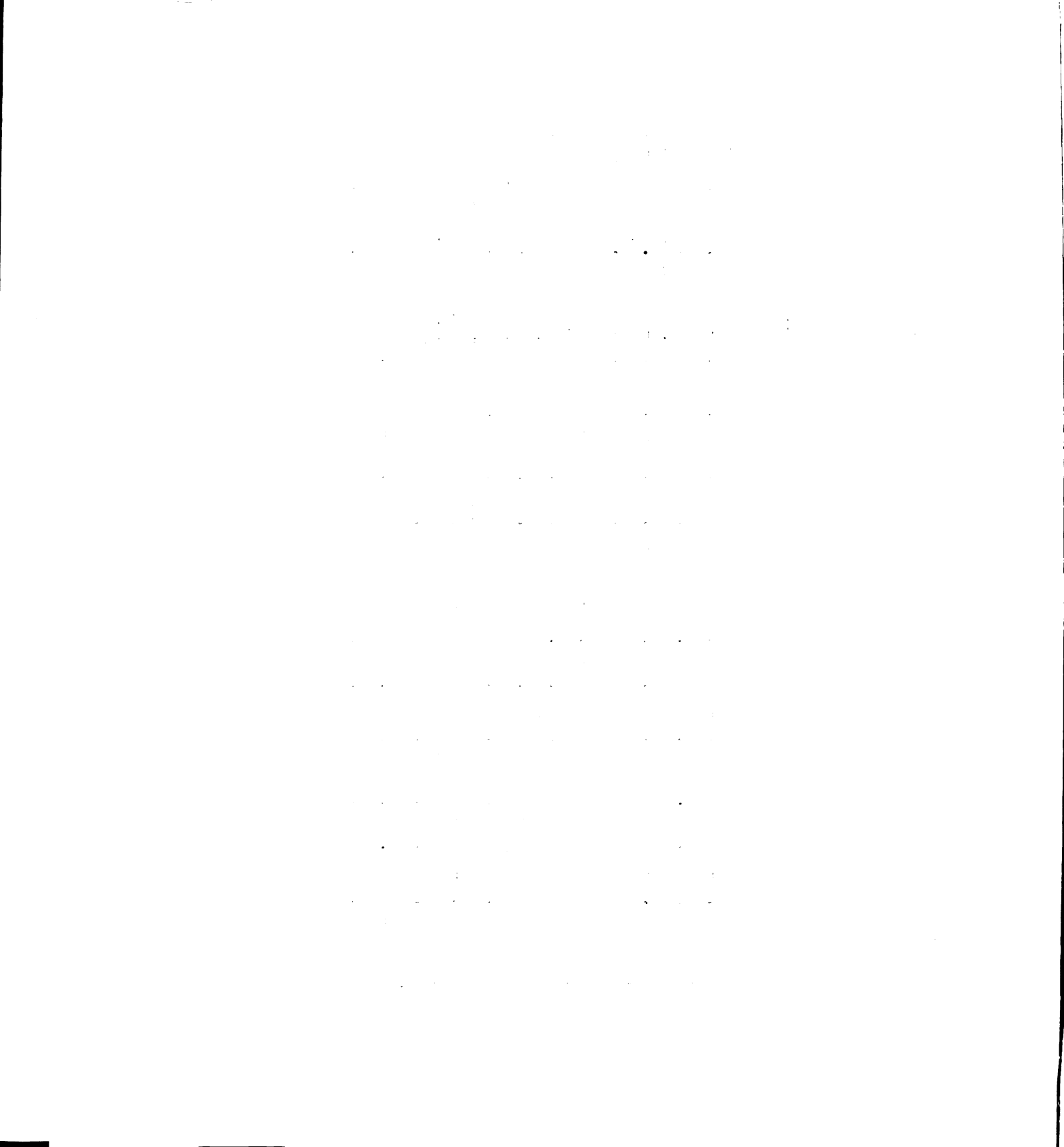


Table A36. Average (repeated measure) Hearing Threshold Level (HTL) and Sound Pressure Level (SPL) thresholds for each subject under each of the warble-tone combinations for 1000 Hz.

| Center Frequency = 1000 Hz | | | | | | | | | | | | | | | | | | |
|----------------------------|-----|-------|-------|---------|-------|-------|---------|-------|-------|---------|-------|-------|---------|-------|-------|---------|---|---|
| Frequency Deviation | | | | | | | | | | | | | | | | | | |
| ±1% | | | | ±3% | | | | ±6% | | | | ±10% | | | | ±50% | | |
| Subject | | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| 1 | | | | 2 | | 3 | 1 | | 2 | 3 | 1 | | 2 | 3 | 1 | | 2 | 3 |
| 1/sec. | HTL | -21.0 | -24.5 | -10.0 | -20.0 | -22.0 | -12.0 | -22.5 | -19.0 | -9.0 | -22.0 | -22.5 | -10.5 | -18.0 | -17.0 | -8.0 | | |
| | SPL | 0.5 | -3.0 | 11.5 | 1.5 | -0.5 | 9.5 | -1.0 | 2.5 | 12.5 | -0.5 | -1.0 | 11.0 | 3.5 | 4.5 | 13.5 | | |
| 2/sec. | HTL | -22.0 | -21.0 | -10.5 | -20.5 | -19.0 | -11.0 | -20.0 | -20.0 | -9.0 | -20.0 | -20.5 | -9.0 | -17.0 | -17.5 | -8.5 | | |
| | SPL | -0.5 | 0.5 | 11.0 | 1.0 | 2.5 | 10.5 | 1.5 | 1.5 | 12.5 | 1.5 | 1.0 | 12.5 | 4.5 | 4.0 | 13.0 | | |
| 4/sec. | HTL | -22.5 | -22.0 | -10.0 | -20.0 | -20.0 | -9.0 | -20.0 | -19.0 | -8.5 | -18.5 | -19.0 | -9.0 | -16.5 | -12.5 | -4.5 | | |
| | SPL | -1.0 | -0.5 | 11.5 | 1.5 | 1.5 | 12.5 | 1.5 | 2.5 | 13.0 | 3.0 | 2.5 | 12.5 | 5.0 | 9.0 | 16.0 | | |
| 8/sec. | HTL | -22.0 | -21.0 | -9.5 | -20.5 | -20.5 | -10.0 | 19.0 | -19.0 | -11.0 | 19.0 | -20.0 | -9.0 | -14.5 | -10.5 | -5.0 | | |
| | SPL | -0.5 | 0.5 | 12.0 | 1.0 | 1.0 | 11.5 | 2.5 | 2.5 | 10.5 | 2.5 | 1.5 | 12.5 | 7.0 | 11.0 | 16.5 | | |
| 16/sec. | HTL | -20.5 | -19.5 | -7.5 | -19.0 | -20.0 | -8.0 | -18.0 | -19.5 | -8.5 | -18.5 | -20.0 | -7.5 | -15.5 | -10.5 | -5.0 | | |
| | SPL | 1.0 | 2.0 | 14.0 | 2.5 | 1.5 | 13.5 | 3.5 | 2.0 | 13.0 | 3.0 | 1.5 | 14.0 | 6.0 | 11.0 | 16.5 | | |
| 32/sec. | HTL | -21.0 | -21.0 | -9.5 | -21.5 | -20.5 | -10.5 | -17.5 | -18.5 | -10.5 | -19.5 | -20.5 | -10.5 | -11.5 | -10.5 | -3.5 | | |
| | SPL | 0.5 | 0.5 | 12.0 | 0.0 | 1.0 | 11.0 | 4.0 | 3.0 | 11.0 | 2.0 | 1.0 | 11.0 | 10.0 | 11.0 | 17.0 | | |
| Modulation Rate | | | | | | | | | | | | | | | | | | |

Modulation Rate

Table A37. Average (repeated measure) Hearing Threshold Level (HTL) and Sound Pressure Level (SPL) thresholds for each subject under each of the warble-tone combinations for 2000 Hz.

| | | Center Frequency = 2000 Hz
Frequency Deviation | | | | | | | | | | | | | | | | | | | | | | | |
|---------|-----|---|-------|------|---------|-------|------|---------|-------|------|---------|-------|------|---------|-------|-------|---------|---|---|---------|---|---|---------|---|---|
| | | ±1% | | | | | | ±3% | | | | | | ±6% | | | | | | ±10% | | | | | |
| | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1/sec. | HTL | -9.0 | -12.0 | -0.5 | -9.0 | -12.0 | 0.0 | -12.0 | -13.0 | -2.5 | -11.5 | -14.0 | -4.5 | -18.5 | -19.5 | -12.5 | | | | | | | | | |
| | SPL | 10.2 | 7.2 | 18.7 | 10.2 | 7.2 | 19.2 | 7.2 | 6.2 | 16.7 | 7.7 | 5.2 | 14.7 | 0.7 | -0.3 | 6.7 | | | | | | | | | |
| 2/sec. | HTL | -11.0 | -11.5 | -1.0 | -11.0 | -14.0 | -2.0 | -9.0 | -1.50 | -3.5 | -8.5 | -13.0 | -2.0 | -18.5 | -17.0 | -11.0 | | | | | | | | | |
| | SPL | 8.2 | 7.7 | 18.2 | 8.2 | 5.2 | 17.2 | 10.2 | 4.2 | 15.7 | 10.7 | 6.2 | 17.2 | 0.7 | 2.2 | 8.2 | | | | | | | | | |
| 4/sec. | HTL | -10.0 | -15.5 | -1.5 | -11.5 | -13.0 | -2.5 | -11.5 | -12.0 | -1.5 | -11.0 | -14.5 | -3.0 | -16.0 | -15.5 | -9.5 | | | | | | | | | |
| | SPL | 9.2 | 3.7 | 17.7 | 7.7 | 6.2 | 16.7 | 7.7 | 7.2 | 17.7 | 8.2 | 4.7 | 16.2 | 3.2 | 3.7 | 9.7 | | | | | | | | | |
| 8/sec. | HTL | -9.0 | -12.5 | -1.5 | -10.0 | -15.5 | -1.5 | -7.0 | -13.5 | -3.0 | -8.0 | -12.0 | -2.5 | -14.5 | -12.0 | -9.5 | | | | | | | | | |
| | SPL | 10.2 | 6.7 | 17.7 | 9.2 | 3.7 | 17.7 | 12.2 | 5.7 | 16.2 | 11.2 | 7.2 | 16.7 | 4.7 | 7.2 | 9.7 | | | | | | | | | |
| 16/sec. | HTL | -12.0 | -12.0 | -1.0 | -11.5 | -13.5 | -1.0 | -7.5 | -13.0 | -0.5 | -7.5 | -11.5 | -2.5 | -15.5 | -12.5 | -9.5 | | | | | | | | | |
| | SPL | 7.2 | 7.2 | 18.2 | 7.7 | 5.7 | 18.2 | 11.7 | 6.2 | 18.7 | 11.7 | 7.7 | 16.7 | 3.7 | 6.7 | 9.7 | | | | | | | | | |
| 32/sec. | HTL | -9.5 | -13.5 | -4.0 | -11.5 | -14.5 | -1.5 | -11.0 | -11.5 | -0.5 | -9.5 | -13.0 | -2.5 | -12.5 | -12.5 | -4.0 | | | | | | | | | |
| | SPL | 9.7 | 5.7 | 15.2 | 7.7 | 4.7 | 17.7 | 8.2 | 7.7 | 18.7 | 9.7 | 6.2 | 16.7 | 6.7 | 6.7 | 15.2 | | | | | | | | | |

Modulation Rate

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud.

2. The second part of the document outlines the specific requirements for record-keeping. It states that all transactions must be recorded in a clear and concise manner, and that the records must be maintained for a minimum of five years.

3. The third part of the document discusses the role of the auditor in verifying the accuracy of the records. It states that the auditor must conduct a thorough review of the records and must report any discrepancies to the appropriate authorities.

4. The fourth part of the document discusses the consequences of failing to maintain accurate records. It states that individuals who fail to comply with the requirements may be subject to fines and penalties.

5. The fifth part of the document discusses the importance of training and education for individuals involved in record-keeping. It states that individuals must be properly trained and educated in order to ensure the accuracy of the records.

6. The sixth part of the document discusses the importance of internal controls in preventing fraud. It states that individuals must implement and maintain effective internal controls to minimize the risk of fraud.

7. The seventh part of the document discusses the importance of transparency and accountability in the financial system. It states that individuals must be transparent and accountable in their actions, and that the financial system must be open to public scrutiny.

8. The eighth part of the document discusses the importance of collaboration and communication between individuals and organizations. It states that individuals must work together to ensure the integrity of the financial system and to prevent fraud.

9. The ninth part of the document discusses the importance of ongoing monitoring and evaluation of the financial system. It states that individuals must regularly monitor and evaluate the system to identify any weaknesses and to make necessary improvements.

10. The tenth part of the document discusses the importance of public participation in the financial system. It states that individuals must encourage public participation and involvement in the system to ensure its transparency and accountability.

Table A38. Average (repeated measure) Hearing Threshold Level (HTL) and Sound Pressure Level (SPL) thresholds for each subject under each of the warble-tone combinations for 4000 Hz.

| | | Center Frequency = 4000 Hz | | | | | | | | | | | | | | | | | |
|---------|-----|----------------------------|------|-------|---------|------|-------|-----------|-------|-------|---------|-------|-------|-----------|-------|-------|---------|-------|-------|
| | | Frequency Deviation | | | | | | | | | | | | | | | | | |
| | | $\pm 1\%$ | | | | | | $\pm 3\%$ | | | | | | $\pm 6\%$ | | | | | |
| | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1/sec. | HTL | -3.0 | -8.5 | -9.5 | -6.0 | -9.5 | -9.0 | -6.0 | -10.5 | -9.5 | -5.0 | -12.0 | -9.5 | -5.0 | -12.0 | -9.5 | -16.0 | -16.0 | -10.5 |
| | SPL | 20.7 | 15.2 | 14.2 | 17.7 | 14.2 | 14.7 | 17.7 | 13.2 | 14.2 | 18.7 | 11.7 | 14.2 | 18.7 | 11.7 | 14.2 | 7.7 | 7.7 | 13.2 |
| 2/sec. | HTL | -4.0 | -8.5 | -9.0 | -4.0 | -9.5 | -9.5 | -5.5 | -8.5 | -8.0 | -4.5 | -10.0 | -10.5 | -4.5 | -10.0 | -10.5 | -14.0 | -14.0 | -10.0 |
| | SPL | 19.7 | 15.2 | 14.7 | 19.7 | 14.2 | 14.2 | 18.2 | 15.2 | 15.7 | 19.2 | 13.7 | 13.2 | 19.2 | 13.7 | 13.2 | 9.2 | 9.7 | 13.7 |
| 4/sec. | HTL | -4.0 | -7.0 | -10.5 | -2.5 | -7.0 | -10.5 | -4.5 | -9.5 | -11.0 | -4.5 | -11.5 | -9.0 | -4.5 | -11.5 | -9.0 | -10.0 | -11.5 | -10.5 |
| | SPL | 19.7 | 16.7 | 13.2 | 21.2 | 16.7 | 13.2 | 19.2 | 14.2 | 12.7 | 19.2 | 12.2 | 14.7 | 19.2 | 12.2 | 14.7 | 13.7 | 12.2 | 13.2 |
| 8/sec. | HTL | -2.0 | -6.0 | -7.0 | -2.5 | -7.5 | -14.0 | -4.5 | -7.5 | -11.0 | -1.5 | -7.5 | -8.0 | -1.5 | -7.5 | -8.0 | -8.5 | -13.0 | -8.0 |
| | SPL | 21.7 | 17.7 | 16.7 | 21.2 | 16.2 | 9.7 | 19.2 | 16.2 | 12.7 | 22.2 | 16.2 | 15.7 | 22.2 | 16.2 | 15.7 | 15.2 | 10.7 | 15.7 |
| 16/sec. | HTL | -2.5 | -7.0 | -7.5 | -8.5 | -9.0 | -10.0 | -3.5 | -9.5 | -10.0 | -4.0 | -7.5 | -10.0 | -4.0 | -7.5 | -10.0 | -10.0 | -12.0 | -7.5 |
| | SPL | 21.2 | 16.7 | 16.2 | 15.2 | 14.7 | 13.7 | 20.2 | 14.2 | 13.7 | 19.7 | 16.2 | 13.7 | 19.7 | 16.2 | 13.7 | 13.7 | 11.7 | 16.2 |
| 32/sec. | HTL | -2.0 | -8.0 | -9.0 | -1.5 | -8.5 | -11.0 | -3.5 | -6.5 | -12.0 | -5.5 | -8.5 | -11.5 | -5.5 | -8.5 | -11.5 | -3.0 | -7.5 | -9.0 |
| | SPL | 21.7 | 15.7 | 14.7 | 22.2 | 15.2 | 12.7 | 20.2 | 17.2 | 11.7 | 18.2 | 15.2 | 12.2 | 18.2 | 15.2 | 12.2 | 20.7 | 16.2 | 14.7 |

Modulation Rate

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1. 2. 3. 4. 5.

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11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533

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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

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Table A39. Average (repeated measure) Hearing Threshold Level (HTL) and Sound Pressure Level (SPL) thresholds for each subject under each of the warble-tone combinations for 8000 Hz.

| | | Center Frequency = 8000 Hz | | | | | | | | | | | | | | | | | |
|---------|-----|----------------------------|------|------|---------|------|------|---------|------|------|---------|------|------|---------|------|------|---------|------|------|
| | | ±1% | | | | | | ±3% | | | | | | ±6% | | | | | |
| | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1/sec. | HTL | 18.0 | 12.5 | 10.5 | 18.0 | 13.0 | 7.0 | 18.5 | 5.0 | 9.0 | 12.5 | 7.5 | 6.5 | 9.5 | 14.0 | 13.0 | 9.5 | 14.0 | 13.0 |
| | SPL | 27.0 | 21.5 | 19.5 | 27.0 | 22.0 | 16.0 | 27.5 | 14.0 | 18.0 | 21.5 | 16.5 | 15.5 | 0.5 | 5.0 | 4.0 | 0.5 | 5.0 | 4.0 |
| 2/sec. | HTL | 17.5 | 14.0 | 17.5 | 16.5 | 14.0 | 10.0 | 17.5 | 8.0 | 5.5 | 11.0 | 10.5 | 7.0 | 8.0 | 12.0 | 12.0 | 8.0 | 12.0 | 12.0 |
| | SPL | 26.5 | 23.0 | 26.5 | 25.5 | 23.0 | 19.0 | 26.5 | 17.0 | 14.5 | 20.0 | 19.5 | 16.0 | 1.0 | 3.0 | 3.0 | 1.0 | 3.0 | 3.0 |
| 4/sec. | HTL | 17.0 | 13.5 | 11.0 | 16.5 | 14.0 | 11.5 | 16.0 | 12.0 | 12.0 | 12.5 | 7.5 | 8.5 | 9.5 | 12.0 | 12.0 | 9.5 | 12.0 | 12.0 |
| | SPL | 26.0 | 22.5 | 20.0 | 25.5 | 23.0 | 20.5 | 25.0 | 21.0 | 21.0 | 21.5 | 16.5 | 17.5 | 0.5 | 3.0 | 3.0 | 0.5 | 3.0 | 3.0 |
| 8/sec. | HTL | 17.0 | 12.0 | 12.5 | 17.5 | 14.0 | 12.5 | 15.0 | 13.0 | 11.0 | 16.5 | 12.0 | 6.0 | 10.0 | 10.5 | 13.0 | 10.0 | 10.5 | 13.0 |
| | SPL | 26.0 | 21.0 | 21.5 | 26.5 | 23.0 | 21.5 | 24.0 | 22.0 | 22.0 | 25.5 | 21.0 | 15.0 | 1.0 | 1.5 | 4.0 | 1.0 | 1.5 | 4.0 |
| 16/sec. | HTL | 19.5 | 12.0 | 10.0 | 18.0 | 13.0 | 16.0 | 17.5 | 12.5 | 7.5 | 16.0 | 9.0 | 8.0 | 9.5 | 7.0 | 12.0 | 9.5 | 7.0 | 12.0 |
| | SPL | 28.5 | 21.0 | 19.0 | 27.0 | 22.0 | 25.0 | 26.5 | 21.5 | 16.5 | 25.0 | 18.0 | 17.0 | 0.5 | 2.0 | 3.0 | 0.5 | 2.0 | 3.0 |
| 32/sec. | HTL | 16.5 | 12.0 | 17.0 | 20.5 | 12.0 | 12.0 | 15.0 | 13.5 | 12.0 | 15.5 | 12.5 | 12.0 | 9.5 | 8.5 | 14.5 | 9.5 | 8.5 | 14.5 |
| | SPL | 25.5 | 21.0 | 26.0 | 29.5 | 21.0 | 21.0 | 24.0 | 22.5 | 21.0 | 24.5 | 21.5 | 21.0 | 0.5 | 0.5 | 5.5 | 0.5 | 0.5 | 5.5 |

Modulation Rate

Journal of Management Studies, 19(1), 67-80.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

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APPENDIX L

**INDIVIDUAL SUBJECT AND MEAN dB DIFFERENCE SCORES FOR
EACH WARBLE-TONE COMBINATION AND FREQUENCY**

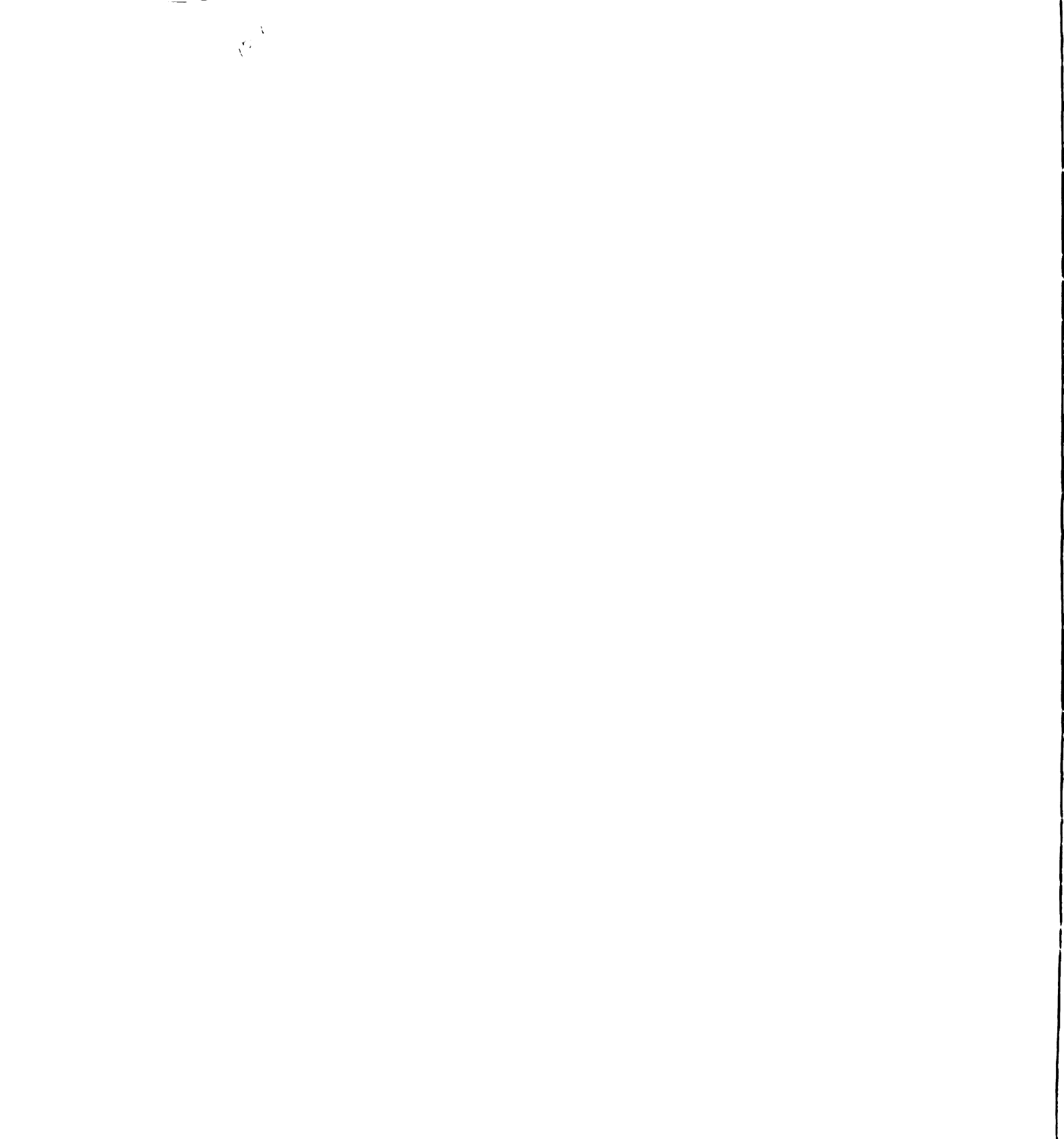


Table A41. Differences in dB of the warble-tone threshold from the pure-tone threshold for all subjects at each combination of frequency deviation and modulation rate, plus the average dB difference for 500 Hz.

| Frequency Deviation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------|--|------|--|------|--|---------|--|------|--|------|--|---------|--|------|--|------|--|---------|--|-----|--|------|--|---------|--|------|--|-----|--|
| ±1% | | | | | | ±3% | | | | | | ±6% | | | | | | ±10% | | | | | | ±50% | | | | | |
| Subject | | | | | | Subject | | | | | | Subject | | | | | | Subject | | | | | | Subject | | | | | |
| 1 | | 2 | | 3 | | 1 | | 2 | | 3 | | 1 | | 2 | | 3 | | 1 | | 2 | | 3 | | 1 | | 2 | | 3 | |
| 1.5 | | -0.6 | | 0.5 | | -1.0 | | -1.1 | | -1.5 | | -1.0 | | -2.6 | | 1.5 | | 0.5 | | 1.4 | | 0.5 | | -1.0 | | -0.1 | | 2.0 | |
| 0.4 | | | | | | -1.2 | | | | | | -0.7 | | | | | | 0.8 | | | | | | 0.3 | | | | | |
| 4.5 | | -0.6 | | 1.0 | | 3.0 | | -0.1 | | 1.0 | | 0.0 | | -0.6 | | 1.0 | | -1.0 | | 0.9 | | 0.0 | | 0.5 | | -0.1 | | 2.0 | |
| 1.6 | | | | | | 1.3 | | | | | | 0.1 | | | | | | 0.0 | | | | | | 0.8 | | | | | |
| 3.0 | | -1.6 | | 0.0 | | 1.5 | | -1.6 | | 0.0 | | 4.0 | | -0.1 | | -1.5 | | 5.5 | | 0.4 | | -3.5 | | 7.5 | | 3.6 | | 2.5 | |
| 0.4 | | | | | | 0.0 | | | | | | 0.8 | | | | | | 0.8 | | | | | | 3.6 | | | | | |
| 1.5 | | -1.6 | | -0.5 | | 0.5 | | -0.6 | | 1.0 | | 5.0 | | 0.4 | | 1.5 | | 1.0 | | 1.9 | | 3.5 | | 5.5 | | -0.6 | | 3.0 | |
| -0.2 | | | | | | 0.3 | | | | | | 2.3 | | | | | | 2.1 | | | | | | 2.6 | | | | | |
| 0.0 | | -0.1 | | 1.5 | | 6.5 | | -1.6 | | 1.0 | | 2.0 | | 0.4 | | -0.5 | | 3.5 | | 0.4 | | 0.5 | | 9.5 | | 2.9 | | 3.0 | |
| 0.4 | | | | | | 1.9 | | | | | | 0.6 | | | | | | 1.4 | | | | | | 5.1 | | | | | |
| 5.0 | | -1.6 | | -1.0 | | -0.5 | | -1.1 | | -0.5 | | 7.0 | | -1.1 | | -0.5 | | 9.0 | | 0.4 | | 0.0 | | 8.5 | | 2.4 | | 3.5 | |
| 0.8 | | | | | | -0.7 | | | | | | 1.8 | | | | | | 3.1 | | | | | | 4.8 | | | | | |
| Modulation Rate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32/sec. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Modulation Rate

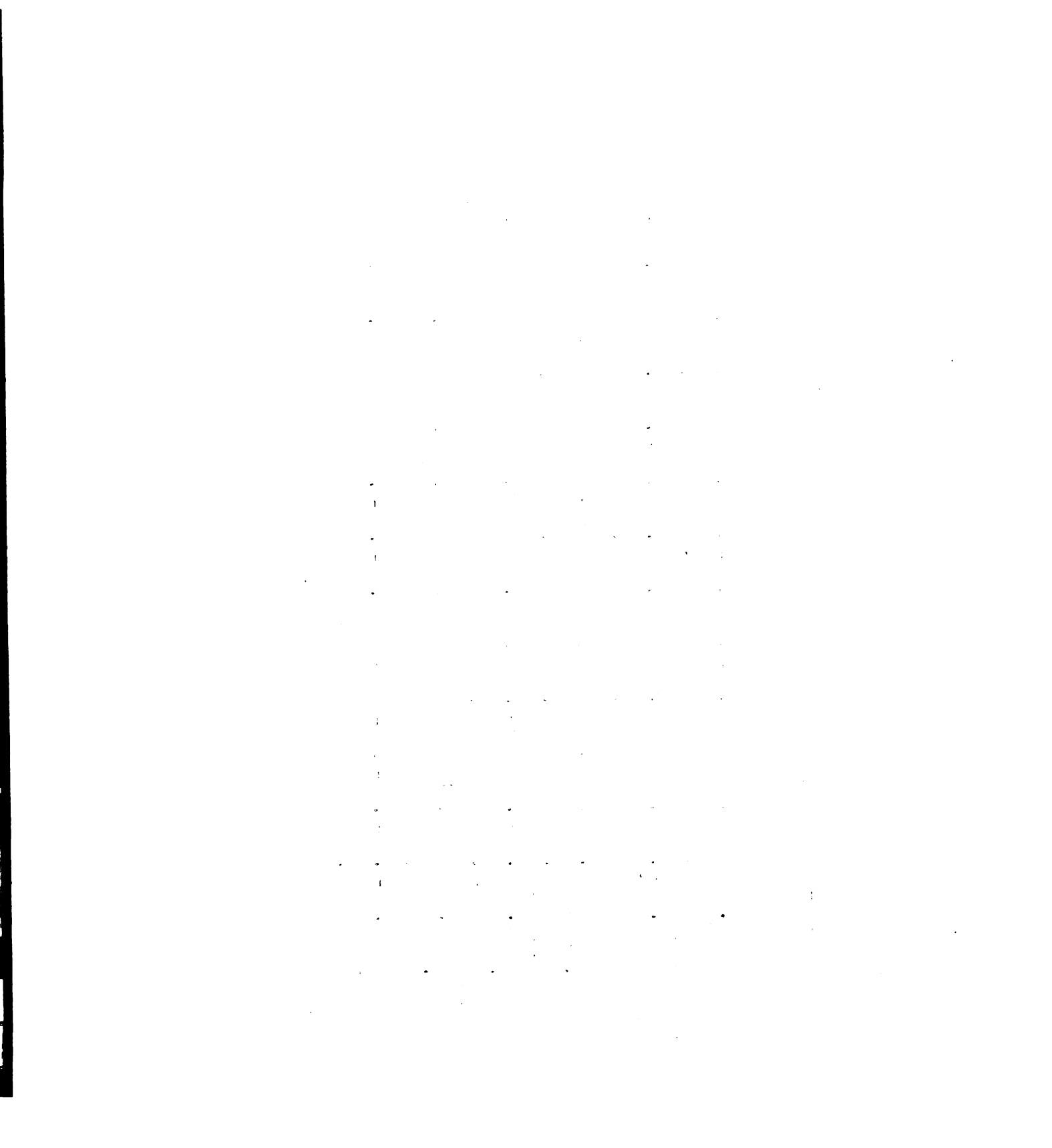


Table A42. Differences in dB of the warble-tone threshold from the pure-tone threshold for all subjects at each combination of frequency deviation and modulation rate, plus the average dB difference for 1000 Hz.

| Frequency Deviation | |
|---------------------|
| ±50% |
| ±10% |
| ±6% |
| ±3% |
| ±1% |
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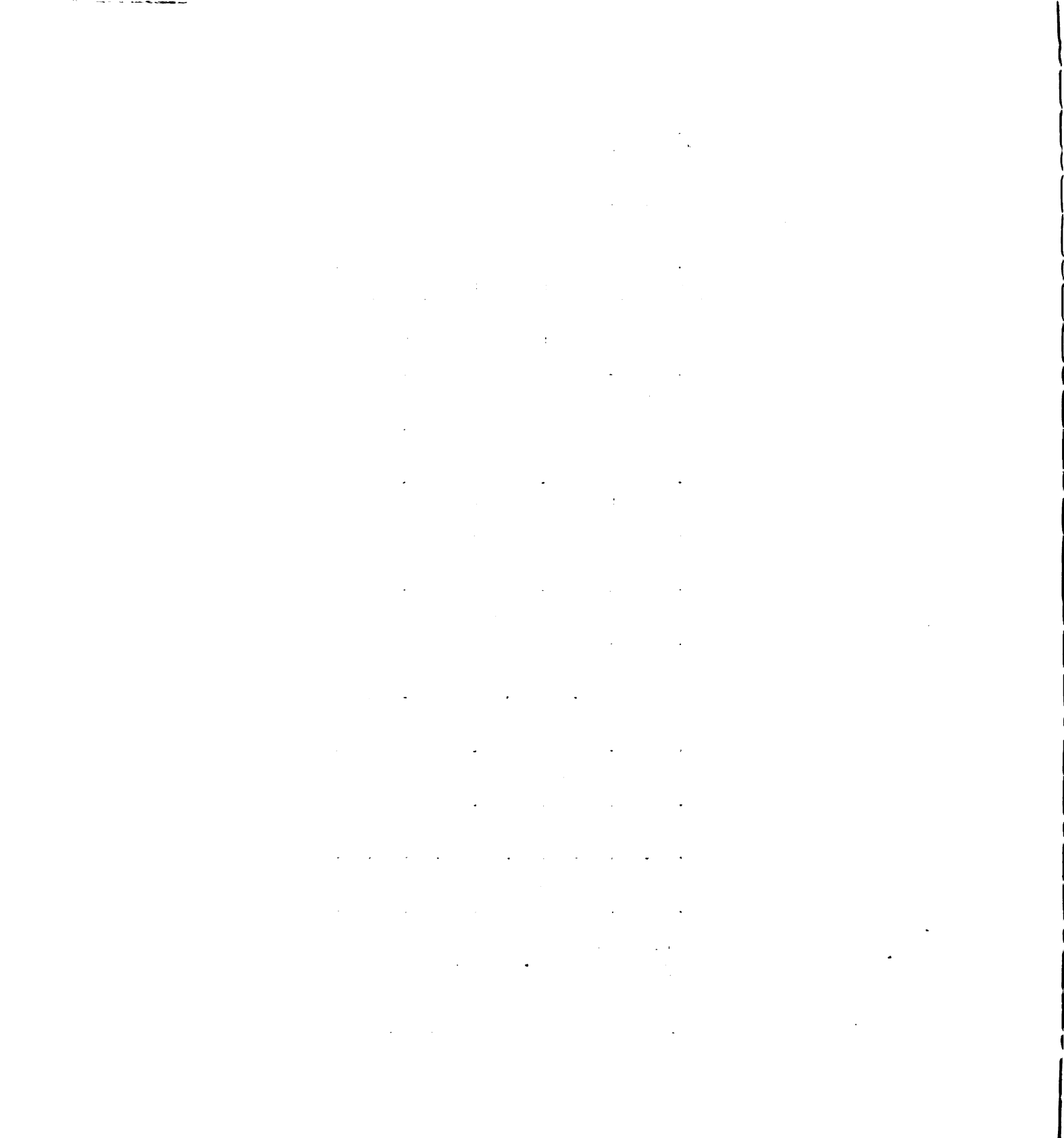


Table 444. Differences in dB of the warble-tone threshold from the pure-tone threshold for all subjects at each combination of frequency deviation and modulation rate, plus the average dB difference for 4000 Hz.

| | | Frequency Deviation | | | | | | | | | | | | | | | | | |
|---------|--|---------------------|------|------|---------|------|------|-----------|------|------|---------|------|------|-----------|------|-------|---------|------|---|
| | | $\pm 1\%$ | | | | | | $\pm 3\%$ | | | | | | $\pm 6\%$ | | | | | |
| | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | | Subject | | |
| | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1/sec. | | -1.0 | -1.5 | -3.5 | -4.0 | -2.5 | -3.0 | -4.0 | -3.5 | -3.5 | -3.0 | -5.0 | -3.5 | -4.0 | -3.5 | -14.0 | -9.0 | -4.5 | |
| | | -2.0 | | | | -3.1 | | | -3.6 | | | -3.8 | | | | | -9.1 | | |
| 2/sec. | | -2.0 | -1.5 | -3.0 | -2.0 | -2.5 | -3.5 | -3.5 | -1.5 | -2.0 | -2.5 | -3.0 | -4.5 | -12.5 | -7.0 | -4.0 | | | |
| | | -2.1 | | | | -2.6 | | | -2.3 | | | -3.3 | | | -7.8 | | | | |
| 4/sec. | | -2.0 | 0.0 | -4.5 | -0.5 | 0.0 | -4.5 | -2.5 | -2.5 | -5.0 | -2.5 | -4.5 | -3.0 | -8.0 | -4.5 | -4.5 | | | |
| | | -2.1 | | | | -1.6 | | | -3.3 | | | -3.3 | | | -5.6 | | | | |
| 8/sec. | | 0.0 | 1.0 | -1.0 | -0.5 | -0.5 | -8.0 | -2.5 | -0.5 | -5.0 | 0.5 | -0.5 | -2.0 | -6.5 | -6.0 | -2.0 | | | |
| | | 0.0 | | | | -3.0 | | | -2.6 | | | -0.6 | | | -4.8 | | | | |
| 16/sec. | | -0.5 | 0.0 | -1.5 | -6.5 | -2.0 | -4.0 | -1.5 | -2.5 | -4.0 | -2.0 | -0.5 | -4.0 | -8.0 | -5.0 | -1.5 | | | |
| | | -0.6 | | | | -4.1 | | | -2.6 | | | -2.1 | | | -4.8 | | | | |
| 32/sec. | | 0.0 | -1.0 | -3.0 | 0.5 | -1.5 | -5.0 | -1.5 | 0.5 | -6.0 | -3.5 | -1.5 | -5.5 | -1.0 | -0.5 | -3.0 | | | |
| | | -1.3 | | | | -2.0 | | | -2.3 | | | -3.5 | | | -1.5 | | | | |

Modulation Rate

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and the role of the accounting department in ensuring the integrity of the financial statements.

2. It is essential for the company to have a clear understanding of its financial position at all times, and this can only be achieved through a robust system of internal controls and a commitment to transparency.

3. The accounting department is responsible for providing timely and accurate information to management, which is crucial for making informed decisions and planning for the future.

4. The document also highlights the need for regular audits and reviews to ensure that the financial statements are free from errors and misstatements.

5. In addition, it emphasizes the importance of maintaining proper documentation and records of all financial transactions, as this is a key requirement for compliance with applicable laws and regulations.

6. The accounting department should also be responsible for monitoring and reporting on the company's compliance with these requirements, and for taking corrective action where necessary.

7. Finally, the document stresses the importance of maintaining a high level of ethical standards and integrity in all financial reporting, as this is essential for maintaining the trust and confidence of stakeholders.



APPENDIX M

**RANKS ASSIGNED TO EACH SUBJECT FOR EACH WARBLE-TONE COMBINATION
FOR KENDALL'S COEFFICIENT OF CONCORDANCE**

RANKS ASSIGNED TO EACH SUBJECT FOR EACH WARBLE-TONE COMBINATION
FOR KENDALL'S COEFFICIENT OF CONCORDANCE

Table A46. Ranks assigned to each subject for thirty warble-tone combinations at 250 Hz.

| Warble-Tone
Combinations | | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--------|--------------------|------|------|-----------------|
| | | 1 | 2 | 3 | |
| 1. | 1%/1 | 30.0 | 15.0 | 12.5 | 57.5 |
| 2. | 1%/2 | 14.0 | 8.0 | 12.5 | 34.5 |
| 3. | 1%/4 | 28.0 | 7.0 | 4.5 | 39.5 |
| 4. | 1%/8 | 11.0 | 19.5 | 19.5 | 50.0 |
| 5. | 1%/16 | 14.0 | 10.0 | 12.5 | 36.5 |
| 6. | 1%/32 | 18.0 | 25.0 | 2.5 | 45.5 |
| 7. | 3%/1 | 18.0 | 26.5 | 7.0 | 51.5 |
| 8. | 3%/2 | 28.0 | 19.5 | 7.0 | 54.5 |
| 9. | 3%/4 | 21.0 | 10.0 | 4.5 | 35.5 |
| 10. | 3%/8 | 24.5 | 22.0 | 19.5 | 66.0 |
| 11. | 3%/16 | 28.0 | 22.0 | 12.5 | 62.5 |
| 12. | 3%/32 | 24.5 | 15.0 | 1.0 | 40.5 |
| 13. | 6%/1 | 8.5 | 24.0 | 24.0 | 56.5 |
| 14. | 6%/2 | 21.0 | 26.5 | 24.0 | 71.5 |
| 15. | 6%/4 | 21.0 | 22.0 | 7.0 | 50.0 |
| 16. | 6%/8 | 18.0 | 15.0 | 29.0 | 62.0 |
| 17. | 6%/16 | 11.0 | 15.0 | 12.5 | 38.5 |
| 18. | 6%/32 | 16.0 | 15.0 | 26.0 | 57.0 |
| 19. | 10%/1 | 7.0 | 15.0 | 2.5 | 24.5 |
| 20. | 10%/2 | 5.0 | 28.0 | 19.5 | 52.5 |
| 21. | 10%/4 | 14.0 | 15.0 | 12.5 | 41.5 |
| 22. | 10%/8 | 24.5 | 29.5 | 12.5 | 66.5 |
| 23. | 10%/16 | 8.5 | 29.5 | 27.5 | 65.5 |
| 24. | 10%/32 | 24.5 | 10.0 | 19.5 | 54.0 |
| 25. | 50%/1 | 1.0 | 1.0 | 19.5 | 21.5 |
| 26. | 50%/2 | 2.0 | 3.5 | 24.0 | 29.5 |
| 27. | 50%/4 | 3.0 | 2.0 | 27.5 | 32.5 |
| 28. | 50%/8 | 5.0 | 3.5 | 19.5 | 28.0 |
| 29. | 50%/16 | 11.0 | 6.0 | 12.5 | 29.5 |
| 30. | 50%/32 | 5.0 | 5.0 | 30.0 | 40.0 |

Table A47. Ranks assigned to each subject for thirty warble-tone combinations at 500 Hz.

| Warble-Tone
Combinations | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--------------------|------|------|-----------------|
| | 1 | 2 | 3 | |
| 1. 1%/1 | 13.0 | 12.0 | 13.0 | 38.0 |
| 2. 1%/2 | 20.0 | 12.0 | 17.0 | 49.0 |
| 3. 1%/4 | 16.5 | 4.0 | 9.5 | 30.0 |
| 4. 1%/8 | 13.0 | 4.0 | 6.0 | 23.0 |
| 5. 1%/16 | 6.5 | 17.0 | 21.0 | 44.5 |
| 6. 1%/32 | 21.5 | 4.0 | 4.0 | 29.5 |
| 7. 3%/1 | 2.5 | 8.0 | 2.5 | 13.0 |
| 8. 3%/2 | 16.5 | 17.0 | 17.0 | 50.5 |
| 9. 3%/4 | 13.0 | 4.0 | 9.5 | 26.5 |
| 10. 3%/8 | 9.0 | 12.0 | 17.0 | 38.0 |
| 11. 3%/16 | 25.0 | 4.0 | 17.0 | 46.0 |
| 12. 3%/32 | 5.0 | 8.0 | 6.0 | 19.0 |
| 13. 6%/1 | 2.5 | 1.0 | 21.0 | 24.5 |
| 14. 6%/2 | 6.5 | 12.0 | 17.0 | 35.5 |
| 15. 6%/4 | 19.0 | 17.0 | 2.5 | 38.5 |
| 16. 6%/8 | 21.5 | 22.0 | 21.0 | 64.5 |
| 17. 6%/16 | 15.0 | 22.0 | 6.0 | 43.0 |
| 18. 6%/32 | 26.0 | 8.0 | 24.0 | 58.0 |
| 19. 10%/1 | 9.0 | 27.0 | 13.0 | 49.0 |
| 20. 10%/2 | 2.5 | 25.5 | 9.5 | 37.5 |
| 21. 10%/4 | 23.5 | 22.0 | 1.0 | 46.5 |
| 22. 10%/8 | 11.0 | 28.0 | 29.5 | 68.5 |
| 23. 10%/16 | 18.0 | 22.0 | 13.0 | 53.0 |
| 24. 10%/32 | 29.0 | 22.0 | 9.5 | 60.5 |
| 25. 50%/1 | 2.5 | 17.0 | 24.0 | 43.5 |
| 26. 50%/2 | 9.0 | 17.0 | 24.0 | 50.0 |
| 27. 50%/4 | 27.0 | 25.5 | 26.0 | 78.5 |
| 28. 50%/8 | 23.5 | 12.0 | 27.5 | 63.0 |
| 29. 50%/16 | 30.0 | 30.0 | 27.5 | 87.5 |
| 30. 50%/32 | 28.0 | 29.0 | 29.5 | 86.5 |

Table A48. Ranks assigned to each subject for thirty warble-tone combinations at 1000 Hz.

| Warble-Tone
Combinations | | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--|--------------------|------|------|-----------------|
| | | 1 | 2 | 3 | |
| 1. 1%/1 | | 7.5 | 1.0 | 10.0 | 18.5 |
| 2. 1%/2 | | 4.0 | 5.5 | 6.0 | 15.5 |
| 3. 1%/4 | | 1.5 | 5.5 | 10.0 | 17.0 |
| 4. 1%/8 | | 4.0 | 5.5 | 12.5 | 22.0 |
| 5. 1%/16 | | 10.0 | 17.5 | 25.5 | 53.0 |
| 6. 1%/32 | | 7.5 | 5.5 | 12.5 | 25.5 |
| 7. 3%/1 | | 14.0 | 3.0 | 1.0 | 18.0 |
| 8. 3%/2 | | 10.0 | 21.0 | 2.5 | 33.5 |
| 9. 3%/4 | | 14.0 | 14.0 | 16.5 | 44.5 |
| 10. 3%/8 | | 10.0 | 9.5 | 10.0 | 29.5 |
| 11. 3%/16 | | 19.0 | 14.0 | 23.5 | 56.5 |
| 12. 3%/32 | | 6.0 | 9.5 | 6.0 | 21.5 |
| 13. 6%/1 | | 1.5 | 21.0 | 16.5 | 39.0 |
| 14. 6%/2 | | 14.0 | 14.0 | 16.5 | 44.5 |
| 15. 6%/4 | | 14.0 | 21.0 | 21.0 | 56.0 |
| 16. 6%/8 | | 19.0 | 21.0 | 2.5 | 42.5 |
| 17. 6%/16 | | 23.5 | 17.5 | 21.0 | 62.0 |
| 18. 6%/32 | | 25.0 | 24.0 | 6.0 | 55.0 |
| 19. 10%/1 | | 4.0 | 2.0 | 6.0 | 12.0 |
| 20. 10%/2 | | 14.0 | 9.5 | 16.5 | 40.0 |
| 21. 10%/4 | | 21.5 | 21.0 | 16.5 | 59.0 |
| 22. 10%/8 | | 19.0 | 14.0 | 16.5 | 49.5 |
| 23. 10%/16 | | 21.5 | 14.0 | 25.5 | 61.0 |
| 24. 10%/32 | | 17.0 | 9.5 | 6.0 | 32.5 |
| 25. 50%/1 | | 23.5 | 26.0 | 23.5 | 73.0 |
| 26. 50%/2 | | 26.0 | 25.0 | 21.0 | 72.0 |
| 27. 50%/4 | | 27.0 | 27.0 | 27.0 | 81.0 |
| 28. 50%/8 | | 29.0 | 29.0 | 28.5 | 86.5 |
| 29. 50%/16 | | 28.0 | 29.0 | 28.5 | 85.5 |
| 30. 50%/32 | | 30.0 | 29.0 | 30.0 | 89.0 |

Table A49. Ranks assigned to each subject for thirty warble-tone combinations at 2000 Hz.

| Warble-Tone
Combinations | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--------------------|------|------|-----------------|
| | 1 | 2 | 3 | |
| 1. 1%/1 | 23.5 | 24.5 | 28.0 | 76.0 |
| 2. 1%/2 | 15.5 | 29.0 | 25.0 | 69.5 |
| 3. 1%/4 | 18.5 | 4.0 | 21.0 | 43.5 |
| 4. 1%/8 | 23.5 | 20.0 | 21.0 | 64.5 |
| 5. 1%/16 | 7.5 | 24.5 | 25.0 | 57.0 |
| 6. 1%/32 | 20.5 | 12.0 | 7.5 | 40.0 |
| 7. 3%/1 | 23.5 | 24.5 | 30.0 | 78.0 |
| 8. 3%/2 | 15.5 | 9.5 | 17.5 | 42.5 |
| 9. 3%/4 | 11.0 | 16.0 | 14.0 | 41.0 |
| 10. 3%/8 | 18.5 | 4.0 | 21.0 | 43.5 |
| 11. 3%/16 | 11.0 | 12.0 | 25.0 | 48.0 |
| 12. 3%/32 | 11.0 | 7.5 | 21.0 | 39.5 |
| 13. 6%/1 | 7.5 | 16.0 | 14.0 | 37.5 |
| 14. 6%/2 | 23.5 | 6.0 | 9.0 | 38.5 |
| 15. 6%/4 | 11.0 | 24.5 | 21.0 | 56.5 |
| 16. 6%/8 | 30.0 | 12.0 | 10.5 | 52.5 |
| 17. 6%/16 | 28.5 | 16.0 | 28.0 | 72.5 |
| 18. 6%/32 | 15.5 | 29.0 | 28.0 | 72.5 |
| 19. 10%/1 | 11.0 | 9.5 | 6.0 | 26.5 |
| 20. 10%/2 | 26.0 | 16.0 | 17.5 | 59.5 |
| 21. 10%/4 | 15.5 | 7.5 | 10.5 | 33.5 |
| 22. 10%/8 | 27.0 | 24.5 | 14.0 | 65.5 |
| 23. 10%/16 | 28.5 | 29.0 | 14.0 | 71.5 |
| 24. 10%/32 | 20.5 | 16.0 | 14.0 | 50.5 |
| 25. 50%/1 | 1.5 | 1.0 | 1.0 | 3.5 |
| 26. 50%/2 | 1.5 | 2.0 | 2.0 | 5.5 |
| 27. 50%/4 | 3.0 | 4.0 | 4.0 | 11.0 |
| 28. 50%/8 | 5.0 | 24.5 | 4.0 | 33.5 |
| 29. 50%/16 | 4.0 | 20.0 | 4.0 | 28.0 |
| 30. 50%/32 | 6.0 | 20.0 | 7.5 | 33.5 |

Table A50. Ranks assigned to each subject for thirty warble-tone combinations at 4000 Hz.

| Warble-Tone
Combinations | | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--------|--------------------|------|------|-----------------|
| | | 1 | 2 | 3 | |
| 1. | 1%/1 | 22.5 | 17.0 | 17.5 | 57.0 |
| 2. | 1%/2 | 17.5 | 17.0 | 22.0 | 56.5 |
| 3. | 1%/4 | 17.5 | 27.0 | 9.0 | 53.5 |
| 4. | 1%/8 | 27.5 | 30.0 | 30.0 | 87.5 |
| 5. | 1%/16 | 25.0 | 27.0 | 28.5 | 80.5 |
| 6. | 1%/32 | 17.5 | 20.0 | 22.0 | 69.5 |
| 7. | 3%/1 | 7.5 | 11.5 | 22.0 | 41.0 |
| 8. | 3%/2 | 17.5 | 11.5 | 17.5 | 46.5 |
| 9. | 3%/4 | 25.0 | 27.0 | 9.0 | 61.0 |
| 10. | 3%/8 | 25.0 | 23.0 | 1.0 | 49.0 |
| 11. | 3%/16 | 5.5 | 14.0 | 13.5 | 33.0 |
| 12. | 3%/32 | 29.5 | 17.0 | 5.0 | 51.5 |
| 13. | 6%/1 | 7.5 | 8.0 | 17.5 | 33.0 |
| 14. | 6%/2 | 9.5 | 17.0 | 26.0 | 52.5 |
| 15. | 6%/4 | 13.5 | 11.5 | 5.0 | 30.0 |
| 16. | 6%/8 | 13.5 | 23.0 | 5.0 | 41.5 |
| 17. | 6%/16 | 20.5 | 11.5 | 13.5 | 45.5 |
| 18. | 6%/32 | 20.5 | 29.0 | 2.0 | 51.5 |
| 19. | 10%/1 | 11.0 | 4.5 | 17.5 | 33.0 |
| 20. | 10%/2 | 13.5 | 9.0 | 9.0 | 31.5 |
| 21. | 10%/4 | 13.5 | 6.5 | 22.0 | 42.0 |
| 22. | 10%/8 | 29.5 | 23.0 | 26.0 | 78.5 |
| 23. | 10%/16 | 17.5 | 23.0 | 13.5 | 54.0 |
| 24. | 10%/32 | 9.5 | 17.0 | 3.0 | 29.5 |
| 25. | 50%/1 | 1.0 | 1.0 | 9.0 | 11.0 |
| 26. | 50%/2 | 2.0 | 2.0 | 13.5 | 17.5 |
| 27. | 50%/4 | 3.5 | 6.5 | 9.0 | 19.0 |
| 28. | 50%/8 | 5.5 | 3.0 | 26.0 | 34.5 |
| 29. | 50%/16 | 3.5 | 4.5 | 28.5 | 36.5 |
| 30. | 50%/32 | 22.5 | 23.0 | 22.0 | 67.5 |

Table A51. Ranks assigned to each subject for thirty warble-tone combinations at 8000 Hz.

| Warble-Tone
Combinations | | Subjects' Rankings | | | Sum of
Ranks |
|-----------------------------|--------|--------------------|------|------|-----------------|
| | | 1 | 2 | 3 | |
| 1. | 1%/1 | 26.0 | 20.0 | 18.0 | 64.0 |
| 2. | 1%/2 | 22.5 | 28.5 | 30.0 | 81.0 |
| 3. | 1%/4 | 19.5 | 25.5 | 19.5 | 64.5 |
| 4. | 1%/8 | 19.5 | 15.5 | 26.5 | 61.5 |
| 5. | 1%/16 | 29.0 | 15.5 | 16.5 | 61.0 |
| 6. | 1%/32 | 16.5 | 15.5 | 29.0 | 61.0 |
| 7. | 3%/1 | 26.0 | 23.0 | 10.5 | 59.5 |
| 8. | 3%/2 | 16.5 | 28.5 | 16.5 | 61.5 |
| 9. | 3%/4 | 16.5 | 28.5 | 21.0 | 66.0 |
| 10. | 3%/8 | 22.5 | 28.5 | 26.5 | 77.5 |
| 11. | 3%/16 | 26.0 | 23.0 | 28.0 | 77.0 |
| 12. | 3%/32 | 30.0 | 15.5 | 23.5 | 69.0 |
| 13. | 6%/1 | 28.0 | 7.0 | 15.0 | 50.0 |
| 14. | 6%/2 | 22.5 | 10.0 | 7.0 | 39.5 |
| 15. | 6%/4 | 13.5 | 15.5 | 23.5 | 52.5 |
| 16. | 6%/8 | 10.5 | 23.0 | 19.5 | 53.0 |
| 17. | 6%/16 | 22.5 | 20.0 | 12.0 | 54.5 |
| 18. | 6%/32 | 10.5 | 25.5 | 23.5 | 59.5 |
| 19. | 10%/1 | 8.5 | 8.5 | 9.0 | 26.0 |
| 20. | 10%/2 | 7.0 | 12.0 | 10.5 | 29.5 |
| 21. | 10%/4 | 8.5 | 8.5 | 14.0 | 31.0 |
| 22. | 10%/8 | 16.5 | 15.5 | 8.0 | 40.0 |
| 23. | 10%/16 | 13.5 | 11.0 | 13.0 | 37.5 |
| 24. | 10%/32 | 12.0 | 20.0 | 23.5 | 55.5 |
| 25. | 50%/1 | 3.5 | 1.0 | 2.5 | 7.0 |
| 26. | 50%/2 | 6.0 | 2.5 | 5.0 | 13.5 |
| 27. | 50%/4 | 3.5 | 2.5 | 5.0 | 11.0 |
| 28. | 50%/8 | 1.0 | 4.0 | 2.5 | 7.5 |
| 29. | 50%/16 | 3.5 | 6.0 | 5.0 | 14.5 |
| 30. | 50%/32 | 3.5 | 5.0 | 1.0 | 9.5 |

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