A STUDY OF THE PERCEPTION OF THE DURATION OF CONTINUOUS, WARBLED AND PULSED SIGNALS

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Patricia Sheafor

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A STUDY OF THE PERCEPTION OF THE DURATION OF CONTINUOUS, WARBLED AND PULSED SIGNALS

By

Patricia Sheafor

AN ABSTRACT

Submitted to
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The purpose of this study is to ascertain the accuracy of human perception of the duration of various auditory signals of the same frequency which vary in duration and method of presentation.

The twenty-five subjects utilized in this study had normal hearing for the frequency involved in the test stimuli and were all college students with a mean age of 25.6 years. Pairs of 1000 cps continuous, warbled and pulsed tones, 6.2-8.6 seconds in duration were randomly arranged and transcribed onto magnetic tape. They were presented at 80 db with the first stimulus always being the reference signal and the second, the variable. The subjects were required to make a three choice judgement of longer, equal or shorter. The subjects were tested in groups and the total time required for the test procedure was approximately one and a half hours.

The findings of this study indicate that subjects had greater difficulty discriminating duration of the shorter stimuli and that the method of presentation did not affect the per cent of correct judgements of duration. Subjects were able to judge duration within .28, .48 and .51 of the standard for each method

of presentation respectively.

The conclusions drawn from this study suggest that one should counterbalance stimuli for methods of constant stimuli used in connection with judgements of duration. Longer time durations are perceived correctly more often. The method of presentation does not affect the per cent of correct responses but the durations necessary to make these judgements do vary with the method of presentation. The subjects show a tendency to use some counting method to estimate the time of duration of sounds. The study of the perception of duration seems to leave itself open for much further research.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The research reported in this thesis has as its purpose to ascertain the accuracy of human perception of the duration of various auditory signals, which though of the same frequency and intensity vary in duration and method of presentation.

The body of this material contains a statement of the problem which will include a hypothesis, a discussion of the distinctiveness of the study, and a definition of the pertinent terms used in this research. This is followed by the review of literature pertaining to the area of sound or signal duration. A discussion of procedures of the study includes (1) a description of the subjects, (2) enumeration of the equipment utilized, and (3) reports the procedures of the experiment. The statistical and graphic analysis of the data and a discussion of these procedures are included as the fourth section of the thesis. The results and significant data are discussed in the summary and conclusions of the study. Implications for further research are also discussed. Finally, the raw data, and samples of procedural items may be found in the appendices.

Hypotheses

The initial impetus for this study came from a discussion of a portion of a research study being performed for the Office of Civil Defense within the Speech and Hearing Science Laboratory at Michigan State University, East Lansing, Michigan. Warning signals and their intensity, duration and alerting properties were under investigation. The question which was raised pertained to the effect of length and type of signal presentation on judgement of signal duration. This discussion transpired into the topic under investigation in the present study.

The specific questions raised for study at this time are:

1. How accurately are human beings able to judge the duration of signals of the same frequency and intensity which vary randomly as to duration and method of presentation, i.e., continuous, warbled, or pulsed?

2. With reference to the units of duration, how great a difference is necessary to make a judgement of difference in duration?

3. Are signals of one type, i.e., continuous vs. warbled or pulsed, more easily differentiated than those of another type?

The third of these three questions lends itself to statistical analysis. The following hypothesis has been formulated on the basis of the third question to facilitate the analysis.

There is no difference in the per cent of correct judgements of duration as a function of the method of signal presentation.

Importance of Study

It becomes evident as one reviews the literature that there has been very little research done in the specific area of judgement of signal duration. This may be more fully seen in the review of literature which is presented in Chapter II.

There have been numerous studies in the areas of acoustic perception, detection of pitch and discrimination of pitch and loudness. However, the majority of these studies have made very little, if any, mention of the methods used to determine the duration of their signals or the effects which these durations had on the auditory perception of their subjects. There are a few studies which have dealt with signal duration but these have either dealt with signals of such short duration that they are classified as clicks, or they have studied the perception of duration of signals introduced in a background of white noise.

In the review of literature Hirsh[1] makes a statement that more of the perceptual system than the ear itself is required to make judgements involving auditory perception. Current audiometric tests utilize the perception of tones and small changes in their intensity as a diagnostic tool in the determination of the location of the lesion.[2] It would seem that further research in the area of perception of sound duration might well lead to new diagnostic tools for central auditory functions.

Thus it would seem that this study is justified not only because it deals with signal duration of at least 6.6 seconds with no background noise but because this area of investigation certainly is a little studied one. It is hoped that this investigation will yield information

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[1] Ira J. Hirsh, "Auditory Perception of Temporal Order," The Journal of the Acoustical Society of America, XXXI (June , 1959), pp. 759-767.

[2] James Jerger, "Hearing Tests in Otologic Diagnosis," ASHA, IV (May, 1962), pp. 139-145.

which will be valuable in terms of adding to the fund of information concerning human audition.

Definition of Terms

There are a number of terms which will be used throughout this discussion that will need to be defined.

The Psychophysical Method of Constant Stimuli is the method which has been utilized in the presentation and analysis of stimuli and data in this study. Hirsh defines psychophysics as:

> the study of the relations between physical stimuli and the responses to which they give rise . . . .The method of constant stimuli is one of three classic psychophysical procedures for measuring the differential or absolute threshold. Stimuli are presented in discrete categories of the independent stimulus dimension. The observer responds with a "yes" or "no," "same" or "different" after each stimulus presentation.[3]

Applying this definition to this study we find that the stimuli were divided into two categories. The reference signal which was always presented first was 1000 cps, constant stimuli 7.6 seconds in duration. The variable signals were randomly arranged in duration and method of presentation and ranged in duration from 6.6 - 8.6 seconds for the continuous and warbled signals and 6.2 - 8.6 seconds for the pulsed data. The subjects responded with judgements of "longer," "equal" or "shorter" after the presentation of each stimulus pair.

The Difference Limen (DL) is one of the methods of analysis of psychophysical data. It is ". . .the increment in a stimulus which is just noticed in a specified fraction of the trials."[4] When three

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[3]Ira J. Hirsh, The Measurement of Hearing (New York: McGraw-Hill Book Company, Inc., 1952), pp. 341, 339.

[4]Ibid., p. 336.

category judgements, i.e., greater, equal, and less, are used the DL may be defined as ". . .the interval of uncertainty IU (or half of it) between the 50-per-cent point on the 'less' and the 50-per-cent point on the 'greater' curve."[5] Guilford states simply that the DL is a stimulus difference that is noticed fifty per cent of the time.[6]

The Point of Subjective Equality (PSE) indicates the central tendency of the judgements. It may be computed as a by-product when limens are the chief point of interest.[7]

The three methods of presentation of stimuli should be defined in order to clarify exactly what methods were used in this study.

The continuous tone was a pure tone of 1000 cps which did not fluctuate as to amplitude or frequency. It was presented as the reference signal throughout the study but was also used as a test stimulus. The warbled tone had a center frequency of 1000 cps and a 5% warble at a rate of 3 and 1/3 cps. The pulsed tone was also a 1000 cps tone having an off time of three tenths of a second and an on time of three tenths of a second. All of these tones were delivered by the same pure tone oscillator from an Allison Audiometer Model 21 B.

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[5] Ibid., p. 13.

[6] J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book Company, Inc., 1954), p. 22.

[7] Ibid., p. 25.

CHAPTER II

REVIEW OF THE LITERATURE

Time and its duration are of intense interest to the human race. There never seems to be enough time or perhaps it is simply that man perceives time with some constant error in his method of perception. The duration of time as perceived in the routine of daily life seems to be affected by factors which are both psychological and physical in nature. The desire for a better control of time, an understanding of its duration, and a comprehension of its effects upon man physically and psychologically has been a constant source of research in many areas of knowledge.

In an attempt to gain a better insight into the area of time study undertaken in this research, the writer has undertaken the following review of literature. The studies of time have been numerous and ascertaining which have dealt with the perception of signal duration has led the writer to divide the pertinent literature into several related areas, (1) time perception, (2) pitch and intensity discrimination, (3) time error and (4) duration.

Time Perception

A study by Woodrow[1] on time perception has been valuable in gaining an over all perspective of the areas involved.

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[1]Herbert Woodrow, "Time Perception," Handbook of Experimental Psychology, ed. S. S. Stevens (New York: John Wiley and Sons, Inc., 1958), Chapter 32, 1224-1235.

Woodrow discusses the temporal stimuli ordinarily used in time studies and describes them as one of two types: (1) empty intervals which are bounded by, for example, two short flashes of light or sound and, (2) sounds or lights lasting continuously over a period of time. The accuracy of discrimination of both the intervals and durations of these types of stimuli have been made for (1) empty intervals bounded by clicks, (2) continuous tones and (3) continuous lights. In a study reported by Woodrow which utilized continuous tones the just noticeable differences between tones was approximately 10 per cent to 12.5 per cent of the standards varying from 0.4 - 2.0 seconds and a considerably larger one for durations of 4 - 30 seconds.[2] Time perception is the result of a special type of reaction to a stimulus. This reaction which facilitates the judgements when comparisons must be made, are affected by objective or environmental factors as well as by the attitude of the subject. The objective factors include the arrangement of the experimental conditions, whether the subject sees a light prior to the onset of the tone, whether he has had practice in making this type of judgement and how long he has been involved in the experimental process. The attitude of the subject refers to the manner in which the subject goes about his task. Some subjects perceive and describe the stimulus as a whole, others seem to pay attention to the first stimulus and then, in some manner, start reproducing it as the second stimulus begins.

Woodrow continues his discussion of various time study prob-

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[2] Ibid., p. 1225.

lems and concludes with a section dealing with theories of time perception. The term protensity is used in this section and pertains to the duration of which one is aware, as distinguished from physical duration. One view of time perception holds that the amount of protensity depends on the physical duration of the experience, as the extensity of a horizontal line depends on the length of the line. However, the concept of protensity has not led to any specific theory to explain the comparison of durations.

Another theory holds that perception of duration can only arise with change. It suggests that time is always indirectly judged by some process which serves as a cue. These cues may be a fading memory image, or a brain trace or they may be connected with attention in such a way that physiologic changes, chiefly some sort of strain, are utilized as the basis of judgements of durations. Some authorities include breathing sensations and counting which is considered to be the most common and accurate method for estimating time in minutes, as temporal cues.

In conclusions Woodrow states:

> Time is not a thing that, like an apple, may be perceived. Stimuli and patterns of stimuli occupy physical time; and we react to such stimuli by perceptions, judgements, comparisons, estimates, etc. Whether some mental variable as duration or protensity is an immediate property of our perception of temporal stimuli, or of mental processes in general, is a matter of some disagreement. If there is no such immediately given property, it follows that time is a concept, somewhat like the value of pieces of money, that attaches to perceptions only through a judgmental process. [3]

Pitch and Intensity Discrimination

This area of study was included in this research not basically

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[3] *Ibid.*, p. 1235.

for its content but in an attempt to determine what intervals and durations were used in previous studies dealing with time.

Green, et al.[4] undertook a study to determine how signal amplitude and duration effect the detectability of a pure tone which was partially masked by random noise. Three experiments were performed. In the first, signal duration was held constant while amplitude was varied; in the second study, signal energy was constant while duration and amplitude were varied; and in the third, amplitude was held constant and duration varied. Not all the findings of this study were pertinent to the present investigation. A few interesting points were made with regard to duration. The authors state that until recently (1956) very little research has been done with signal duration, and the question of how duration effects the hearing mechanism is an important aspect of the study of duration. They included a rather extensive coverage of previous studies concerned with signal detection and the writer was interested in these chiefly for the time intervals stated. Yet even these were not specifically applicable to the present study.

In a study conducted by Hirsh,[5] he examined the judgement of temporal order and the kinds of physical changes that are necessary in order that there be perceived changes. The stimuli utilized in this research were very short and were classified as clicks.

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[4]David M. Green, Theodore G. Birdsall, and Wilson P. Tanner, Jr., "Signal Detection as a Function of Signal Intensity and Duration," The Journal of the Acoustical Society of America, XXIX (April, 1957), pp. 523-531.

[5]Ira J. Hirsh, "Auditory Perception of Temporal Order," The Journal of the Acoustical Society of America, XXXI (June, 1959), pp. 759-767.

He found that a temporal separation of 2 msec. is sufficient to give rise to the perception of two sounds and that a separation of 20 msec. enables subjects to determine 75% of the time which of the sounds came first. He concludes that more of the perceptual system than the ear itself is required to make such a judgement and thus temporal order judgements do not seem to be closely related to factors which have been shown to be important for the peripheral auditory system.

Konig's[6] study deals with the effect of interstimulus interval on pitch discrimination. Here again the chief points of interest to the writer had to do with the duration of signals. Konig points out that the pitch of a tone depends on its duration and that as the duration is lessened the tonal characteristics disappear and the tone sounds like a click. He found that the best performance of his subjects was attained with an interstimulus interval of 2.5-5 seconds.

However, the studies cited previously have used intervals of from 20 mesc to 4 seconds (Hirsh, Green, Woodrow). The actual duration of the test stimuli in these studies have varied as much as the intervals. Thus one is left with little specific knowledge of which durations are most applicable to the present research, and also with very little understanding of the factors used to determine the above mentioned intervals and durations.

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[6] E. Konig, "Effects of Time on Pitch Discrimination Thresholds under Several Psychophysical Procedures; Comparison with Intensity Discrimination Thresholds," The Journal of the Acoustical Society of America, XXIX (May, 1957), pp. 606-612.

Time Error

The function of the time error in psychophysical methods is of importance and two rather extensive studies were reviewed on the subject.

Koester's study[7] was done in relation to pitch and loudness discrimination but deals to a great extent with time error. When a subject involved in a psychophysical experiment compares two successive stimuli which are equal or slightly different in quality or intensity, the second stimuli is often over or underestimated, with reference to the first. Over-estimation is the more common type of error and is referred to as a negative time error. When the second stimuli is under-estimated this is referred to as a positive time error.

The study contains eight experiments which deal chiefly with the pitch and loudness discrimination. The results which dealt with time-error seem to indicate that time-error cannot be accounted for by a single cause. The major sources of the constant error seem to be (1) stimulus level, (2) the type of impression, (3) amount of practice and (4) experimental procedure. It is also pointed out that the amount of time between stimuli does not seem to have as much effect as the above mentioned factors on the time error.

Another study dealing with time error is that reported by

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[7]Theodore Koester, "The Time Error and Sensitivity in Pitch and Loudness Discrimination as a Function of Time Interval and Stimulus Level," Archives of Psychology, ed. R. S. Woodworth, No. 297, (May, 1945), p. 69.

Stott.[8] The purpose of his investigation was to ascertain the occurrence of time-error which is found in the comparison of short continuous tones. He was also interested in the location of the indifference duration which he defines as the duration at which time-errors disappear. Most of the work was concentrated on durations of 0.5-2.0 seconds.

The two major findings relevant to the present study indicate that the previous experience of a subject in comparing durations is a very important factor in determining time-errors. Also Stott feels that in order to minimize the effects of experience large numbers of subjects should be used and only the judgements made in the early portion of the experimental sessions should be considered.

Duration

Studies dealing specifically with the perception of duration of signals seem to be difficult to find. In her research the writer has found only two studies which have had duration as their chief point of concern.

The first study concerned with signal duration was done by Small and Campbell and the results were published in Acta Psychologica.[9] Thus the information available is rather limited. The subjects in the study were asked to judge whether the second number of a stimulus pair was longer or shorter than the first.

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[8] L. H. Stott, "Time-Order Errors in the Discrimination of Short Tonal Durations," Journal of Experimental Psychology, XVIII (1935), pp. 741-766.

[9] A. M. Small and R. A. Campbell, "Differential Sensitivity for Temporal Intervals with Auditory Stimulation," Acta Psychologica, XIX (1961), pp. 557-558.

The standard stimuli was maintained constant and the duration of the variable stimulus was randomly varied. The findings include the following: (1) the inter-stimulus interval became less important as a variable as duration lengthened, (2) listeners generally over-estimated the duration of the standard stimulus and (3) the data of the study did not make it possible to determine whether listeners were basing their judgements on duration alone, loudness alone or a combination of the two. If loudness is the determining factor in such judgements then it should be much more carefully controlled.

The second study found by this researcher was a Ph.D dissertation entitled "Human Discrimination of Auditory Duration."[10]

The study utilized a two-alternative-forced-choice procedure. Two sine-wave signals of the same amplitude and frequency which differed only in duration were presented in sequence at each trial. The order of the presentation of stimuli was random and the subjects' task was to state, for each trial, which of the signals had occurred first, the longer or shorter one. The signals were presented in a background of white noise.

The results of this study indicate that duration measurement was accomplished by a "counting mechanism" and that the source of these impulses was random. Limitations on performance were assumed to come from uncertainty regarding the end-

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[10] C. D. Creelman, "Human Discrimination of Auditory Duration," (Ph.D. dissertation, University of Michigan), Dissertation Abstracts, XXII, (July, 1961), p. 331.

points of the time interval, and from memory limitations. No definite findings are stated as to the perception of duration by the subjects in this study.

CHAPTER III

SUBJECTS, EQUIPMENT, AND TESTING PROCEDURES

Subjects

The twenty-five subjects utilized in this study were students at Michigan State University, East Lansing, Michigan. Thirteen of the subjects were not affiliated with the area of Speech and Hearing Science, the remaining twelve subjects were graduate students in Speech and Hearing Science. All of the subjects were screened at 15 db at 1000 cps, the frequency involved in the test procedure, and were judged to have normal hearing for that frequency. There were thirteen female subjects and twelve male subjects ranging in age from twenty to forty-six years. The mean age of the subjects was 25.6 years.

Equipment

Hearing screening for all subjects was accomplished with an audiometer (Audiovox Model 7 BT, serial number 2232) with a matched pair of earphones (Telephonics TDH-39).

The equipment utilized was:

1. Audiometer, (Allison Model 21 B);
2. Tape recorder, (Wollensak Model T 1500);
3. Recording tape, (Scotch Tenzar Backing Magnetic Tape 311);
4. Tape recorder for the production of the test tapes, (Ampex Model 601);

5. Tape recorder for the presentation of the taped stimuli, (Ampex Model 602);

6. Earphones, a panel of twelve binaural earphones, (Telephonics TDH-39);

7. Timer, (Hunter Timer, Modal 100 B) which was capable of presenting pulses at lengths variable from one millisecond to ten seconds in steps of one millisecond and,

8. Graphic Level Recorder (Bruel and Kjaer Model 2305).

Two block diagrams of the equipment used for the recording and presentation of the test tapes follow.

Figure 1 -- Record and timing system employed in production of test tapes.

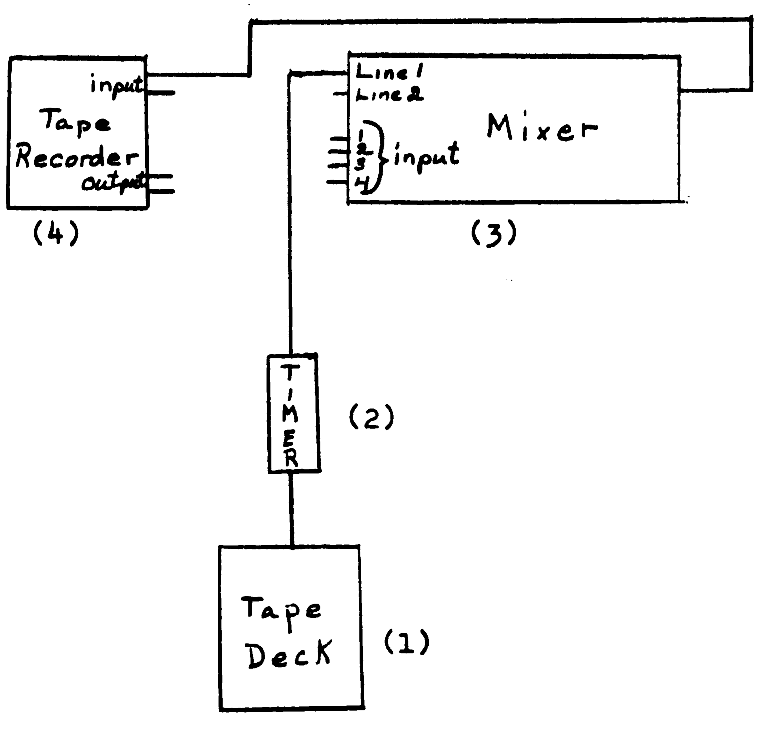

Figure one illustrates the instrumentation for the tape recording of the test stimuli. It includes, as numbered in the figure, (1) the tape recorder (Ampex 601) from which the taped stimulus tones were sent through (2) the timer (Hunter Timer, Model 100 B) where the duration of the signal was determined, into (3) an Ampex Stereo Mixer from whence the signals progressed to (4) a tape recorder (Ampex 602) on which the test tapes were recorded.

Figure 2 -- Playback system for presentation of test tapes.

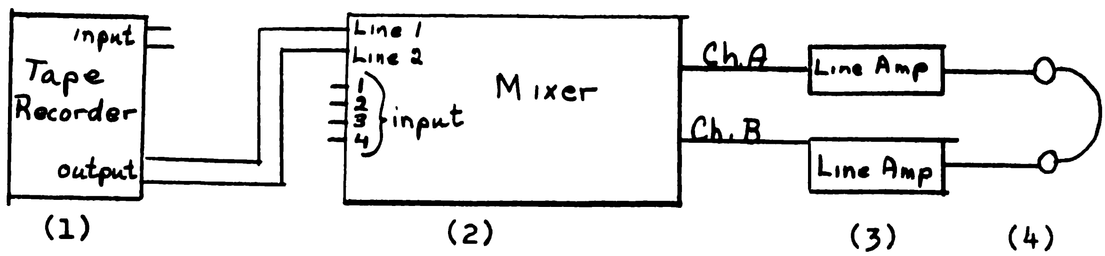

Figure two illustrates the equipment used for the playback system. Here the (1) tape recorder (Ampex 602) was the source for the signal presentation, (2) the Ampex Stereo mixer is again utilized, (3) two amplifiers are added and (4) the test stimuli are fed into the panel of twelve earphones (Telephonics TDH-39).

Procedure

As the subjects entered the testing room, their hearing was screened by the researcher. The test procedure was carried out in the Speech and Hearing Science Laboratory at Michigan

State University. This area was relatively quiet throughout the experimental proceedings.

The pure tone stimuli used in the test tapes were presented in pairs and distributed as follows: A-C were practice pairs at 500 cps, 1-165 were test pairs at 1000 cps. The first tone in each test pair was always a continuous signal and was considered to be the reference tone. This tone always was 7.6 seconds in length. The second tone in each pair ranged randomly in length from 6.6 seconds to 8.6 seconds and varied also as to method of presentation. All pairs were presented to the subjects at 80 db relative to 0.0002 dyne/cm^2.

The subjects were seated in a panel of twelve chairs with the earphones plugged into jacks on each chair. The subjects were given a response sheet (sample in appendix) on which to place their judgements and then were given the following instructions:

> We are performing this test in order to ascertain how accurately length of sound is perceived with varying types of signals. You will hear three types of signals--continuous, pulsed and warbled. They will be presented in pairs with the first sound always being the reference tone. You are to make a judgement as to the length of the second sound as compared to the first or reference signal.
>
> You may use any method of measurement you desire provided it does not involve a watch or does not disturb your neighbors. Thus tapping your finger or foot is not permissible unless you can do it unobtrusively.
>
> Your response sheet is made out in such a way that all you must do is mark the appropriate square following the numbered pair. You will be told the number of each pair prior to hearing the signals. The first three pairs of sounds are practice pairs. We will do these first to acquaint you with the procedure. Place a mark in either the longer, equal or shorter column when you have made your judgement as to the length of the second sound as compared to the first.

Immediately following these instructions the subjects adjusted their earphones and the three practice pairs were initiated. The practice pairs differed from the test pairs in that they were made up of 500 cps tones and the differences in duration were of greater magnitude, being of at least one second in length. Upon completion of the three practice pairs, the subjects were told what the responses should have been. If there were any subjects who had not made any correct responses to these gross differences, the practice items were given again. Following the practice items the subjects were asked to remove their watches and the following instructions were given.

> Now we will start the experiment. You will have to pay very close attention because many of the differences are much smaller than those you heard in the practice pairs.

As there were twenty-five subjects, the testing was performed in three separate sessions. Four subjects were tested initially, nine subjects in the second session, and twelve in the final testing session. The testing time was approximately one and one half hours, with a short break at the half-way point while the tapes were being changed.

It was felt that the subjects who heard the test tape in sequence from 1-165 might do poorly on the first part of the tape due to unfamiliarity with the task, and also on the second half of the test due to fatigue. However, they might also profit from the learning experience of the first half of the tape and so show improvement on the second section of the tape. Therefore, the first thirteen subjects heard the test tape in sequence from 1-165. The second group, consisting of twelve subjects, heard the test tape from A-C, 82-165, and 1-81. This procedure was followed in order to minimize the learning and fatigue factors that might occur.

After the test procedure was completed, the subjects were asked to note on the back of the response sheet which, if any, method they had used to time the signals.

Upon completion of the experimental testing, the exact duration of the pulsed stimuli was brought under question due to its characteristic three tenths of a second "on-off" pattern. Thus, the duration of the pulsed signals could only be exactly as planned if the timer happened to turn on exactly in the middle of an "on" pulse and also turn off in the middle of an "on" pulse. The pulsed signals could vary as much as six tenths of a second from the expected duration depending on the point at which the timer initiated the signal.

In order to determine the recorded characteristics of the pulsed signals, it was decided that all pulsed signals should be put through the Bruel and Kjaer Graphic Level Recorder to test their durations. During this investigation it was found that (1) the Hunter timer had produced a constant error of four tenths of a second and had thus shortened all signals by this amount, (2) the duration of the pulsed signals varied greatly from signal to signal and (3) that the signal relationships for randomly selected continuous and warbled signals, though shortened, were the same. Thus, the original time interval of eleven steps in duration from seven to nine seconds was modified to be eleven steps in duration with two tenths of a second difference from 6.6 seconds to 8.6 seconds. There are nineteen steps in duration of the pulsed data ranging from 6.2 seconds to 8.6 seconds. The exact order of the original tapes may be found in the appendices with the appropriate revisions made for the pulsed data.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The results of the experiment were tabulated and subjected to two statistical procedures. The analysis-of-variance technique as described by Dixon and Massey[1] was utilized. The formuli are presented in the table below.

Table 1. Analysis-of-variance table for one variable

	Sum of Squares	df	Mean Square	Estimate of
Means	$\frac{\Sigma T_{i+}^2}{n_i} - \frac{T_{++}^2}{N}$	K-1	sm^2	$\sigma^2 + n\sigma m^2$
Within	$\Sigma\Sigma xij^2 - \frac{\Sigma T_{i+}^2}{ni}$	N-k	sp^2	$\sigma 2$
Total	$\Sigma\Sigma X1_j^2 - \frac{T_{++}^2}{N}$	N-1		

The data, over time, for the judgements for each method of presentation were converted to percentages and the one way analysis-of-variance technique described above was utilized to ascertain if there was any relationship between per cent of correct judgements of duration and methods of presentation. The tables below show the data involved in this analysis.

[1] Wilfred J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis (New York: McGraw-Hill Book Company, Inc., 1957), pp. 145-152.

Table 2. Mean percentages of correct responses

	Continuous	Warbled	Pulsed
Mean %	53.89	55.45	51.87

Table 3. Summary of Analysis-of-Variance

Source	df	SS	MS	F
Columns	2	88.75	44.37	.154
Within	36	10341.88	287.27	
Total	38	10430.63		

The findings of this analysis indicate that there was no significant relationship between the per cent of correct judgements and the method of presentation.

Following this procedure the data for each method of presentation were plotted on graph paper and lines of best fit were drawn by inspection. Prior to determining the difference limens, a least squares procedure, as described by Blalock[2] was utilized to verify the lines of best fit. It was found that those drawn by inspection had in most cases been exact or very close to those calculated by using the formuli given below.

$$b = \frac{N \sum XY - (\sum X)(\sum Y)}{N \sum X^2 - (\sum X)^2}$$

$$a = \frac{\sum Y - b \sum X}{N}$$

$$Yp = a + bX$$

[2]Hubert M. Blalock, Jr., Social Statistics (New York: McGraw-Hill Book Company, Inc., 1960), pp. 283-284.

The three graphs that follow on pages 25, 26, and 27, contain the data plotted with the calculated lines of best fit for the "shorter" and "longer" judgements. The lines of best fit for the "equal" data were drawn by inspection.

It was found after plotting the data that the results were skewed toward the short end of the time scale. This is due to the presence of a positive time error. In other words, the subject's perceived the first or reference signal as being longer than it was. This caused them to make judgements of the duration of the variable signal in error as compared to the standard. They consistently judged the variable signal to be shorter than it was, thus skewing the data. Such a phenomenon is due to the bias which may arise when the stimuli are presented successively. In this study the first stimulus was always the reference signal and it would appear that this has caused the positive time error, meaning that the apparent magnitude of the first stimulus is enhanced as time passes.[3]

Koester discusses the "time-error" and states that:

> . . . whatever is retained (memory image, muscular set, trace, etc.) as a basis for a comparison judgement must undergo some sort of progressive change during the time-interval which elapses before the second stimulus is applied . . . Gestalt psychologists such as Koffka (19) have found here the experimental basis for an elaborate tract theory according to which the occurrence of the "time" error is attributed to the fact that sensory impressions are represented in the brain as electrochemical excitations or traces which undergo fading, displacement, and transformation with time. [4]

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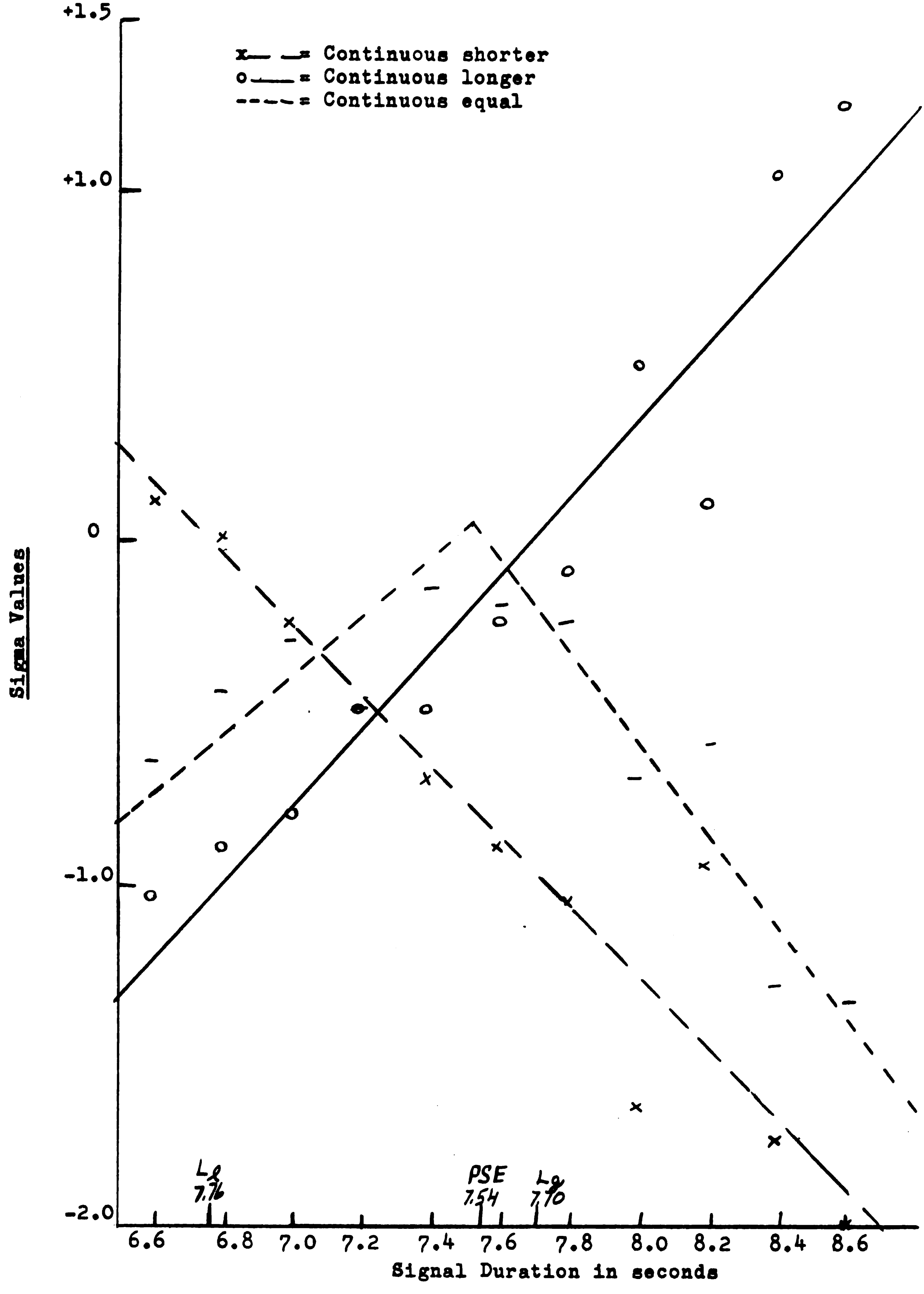
[3]Burton G. Andreas, Experimental Psychology (New York: John Wiley and Sons, Inc., 1960), pp. 121-122.

[4]Koester, loc. cit., pp. 5-6.

Figure 3. Graphic representation of responses for continuous data



+1.5
+1.0
0
-1.0
-2.0
x— —= Continuous shorter
o——= Continuous longer
----= Continuous equal
Sigma Values
PSE
7.54
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
Signal Duration in seconds

Figure 4. Graphic representation of responses for warbled data

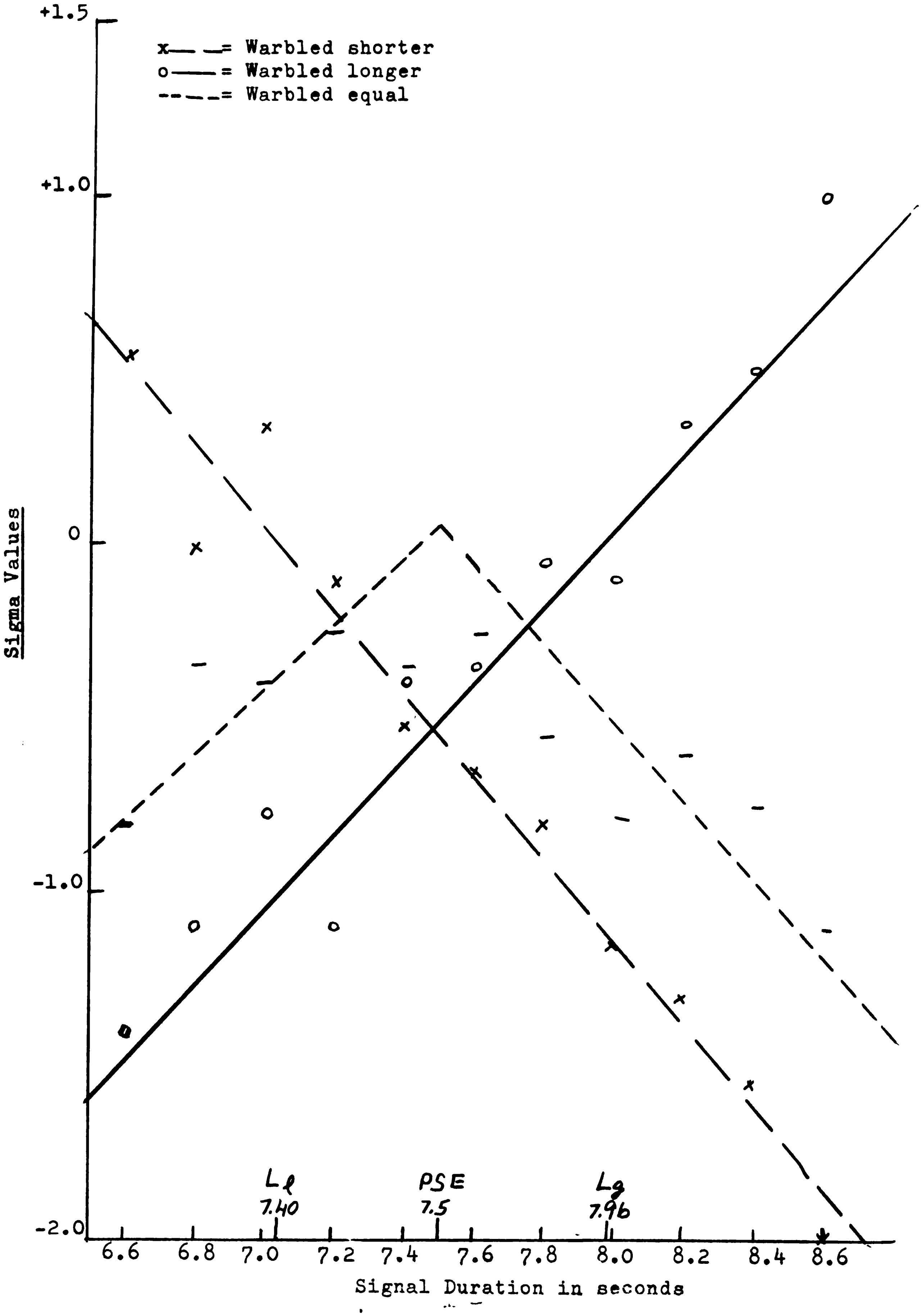
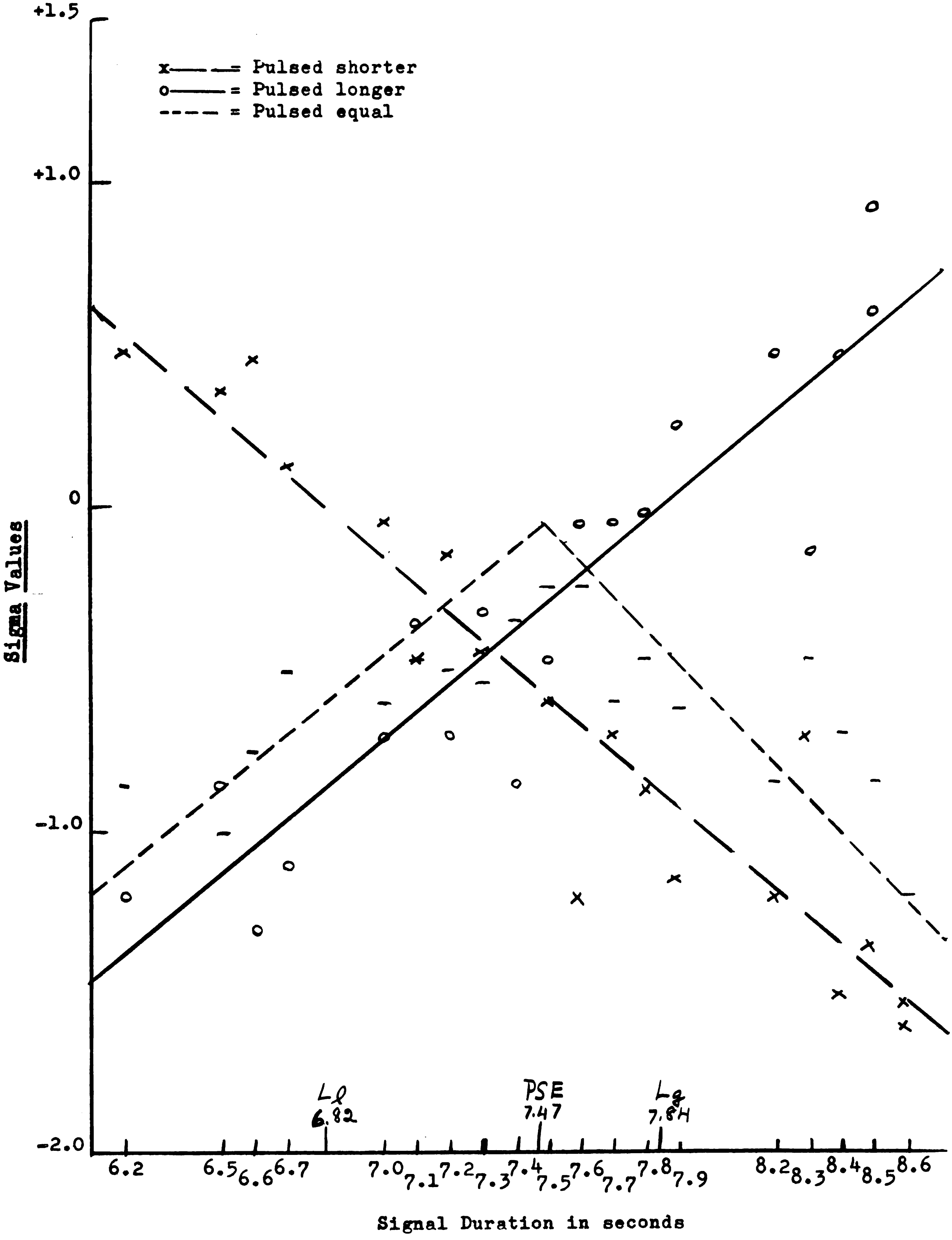

+1.5
x— —= Warbled shorter
o——= Warbled longer
----= Warbled equal
+1.0
0
-1.0
-2.0
Sigma Values
Lℓ
7.40
PSE
7.5
Lg
7.96
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
Signal Duration in seconds

Figure 5. Graphic representation of responses for pulsed data


+1.5
+1.0
0
-1.0
-2.0
x——— = Pulsed shorter
o——— = Pulsed longer
---- = Pulsed equal
Sigma Values
Lℓ
6.82
PSE
7.47
Lg
7.84
6.2
6.5
6.6
6.7
7.0
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8.2
8.3
8.4
8.5
8.6
Signal Duration in seconds

The positive time error is apparent in all three of the graphs but is especially noticed for the pulsed and continuous data. The present researcher did not design her study in such a way that the correction for time error could have been made by counterbalancing. This would have involved presenting the reference tone both as the first and as the second stimulus. This could have been accomplished, without informing the subjects of the possibility of change, and could have been allowed for in the scoring procedures.

Difference limens were obtained for the three methods of presentation. The interval of uncertainty (IU) for the continuous data was from a lower DL of 6.76 seconds to an upper limen of 7.70 seconds, an interval of .96 seconds. The DL being half of the IU, was .48 seconds. The warbled data had an IU of .56, from 7.40 to 7.96 seconds, and a DL of .28 seconds. The pulsed data had the largest IU of 1.02 seconds, from 6.82 to 7.84 seconds, with a corresponding DL of .51 seconds.

The point of subjective equality (PSE) was computed using the arithmetic means of the "equal" data.[5] The continuous PSE was 7.54 seconds, 106 seconds from the point of equality set in the study--7.6 seconds. The warbled PSE was 7.5 seconds, .1 of a second from the stated point of equality and the pulsed PSE was at 7.47 seconds, .13 of a second from the point of equality for the study stated above.

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[5]Guilford, loc. cit., p. 138.

Discussion

In the statement of the problem in Chapter I, three questions were raised with regard to the research to be accomplished. With the completion of the compilation and analysis it becomes readily apparent that answers, or partial answers have been found to these questions. It also becomes obvious that other questions have been raised which open areas for future research.

The analysis of the data for per cent of correct responses and their relationship to the method of presentation indicates that one method of presentation did not facilitate correct judgements of duration any more than another. This can also be seen by an inspection of the graphs. Thus, one fails to reject the hypothesis proposed in Chapter I, i.e., there is no difference in the per cent of correct judgements of duration as a function of signal presentation.

Subjects had greater difficulty differentiating the shorter stimuli and this would seem to be due to the presence of a positive time error. This indicates that the duration of the first stimulus was lengthened with the passage of time. Thus the lower DL's were larger for all methods of presentation than the upper DL's. In future research it would be interesting to design the study and counterbalance the stimuli to eliminate time error as much as possible.

The duration necessary for judgements of difference to be made, varies with the methods of presentation. These durations are expressed as the DL, and it must be kept in mind that the DL is indicated by the boundaries of the interval of uncertainty, and at this time interval the subjects are only getting fifty-per-cent or more correct responses. It is difficult to determine the necessary duration for 100 per cent correct responses from the data collected in this study. The highest per cent correct was 88.8 per cent at 8.6 seconds on the continuous signal data. It would seem, however, that the difference in duration must be of at least one second in order to have 100 per cent correct responses.

The reason for the difference limen being placed as it is from a fifty-per-cent point is because with a three choice response--longer, equal, or shorter--the subjects had a .33 chance of guessing correctly. Thus when the difference limen is dropped from a fifty-per-cent point this is greater than the probability of chance alone.

It was found that the subjects required a duration of at least .28 of a second to make difference judgements for warbled signals, .48 of a second for continuous signals, and .51 of a second for pulsed signals.

The point of subjective equality indicates what signal duration the subjects felt was equal to the specified equal test stimulus. The PSE for pulsed data was 7.47 seconds, for warbled signals, 7.5 seconds, and for continuous signals 7.54 seconds.

An interesting by-product of this research has been an informal notation and tabulation regarding the methods used by the subjects to time the duration of the signals. It will be remembered that the subjects were asked to note on the back of their response sheet, what, if any, method they had used for timing. Creelman states, "Duration measurment was assumed to be accomplished by a 'counting mechanism,' operating on impulses generated over the relevant duration."[6]

It was found that the majority of subjects used some counting device such as marking, tapping, chewing, feeling their pulse or simply counting. A few reported holding their breath and a few stated that they "felt" the duration of the signals. A great many subjects used more than one method of timing during the hour session.

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[6]Creelman, loc. cit., p. 331.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Much of the emphasis in research on perception of time has been placed on discrimination and detection of various signals. The aspect of time study covered in this investigation, i.e., the perception of duration, has not been studied exhaustively. The study of perception of duration presents many possibilities for further research, as well as the possibility of being of benefit to man as a possible diagnostic tool for central auditory functions.

The purpose of this study has been to ascertain the accuracy of human perception of the duration of various auditory signals in an effort to gain a greater understanding and knowledge of this area of endeavor.

A review of the literature pertaining to this study indicates that little research has been performed with the duration of the signals being the major concern. Duration has been a part of most studies of time perception but has not been investigated in any great detail with reference to perception. Thus, this study seems to be one of a limited number.

The subjects for this study were twenty-five college students with a mean age of 25.6 years. It was determined that all subjects had normal hearing for the frequency utilized in the study. The test stimuli consisting of pairs of randomly arranged continuous, warbled and pulsed tones of from 6.2 - 8.6 seconds in duration and of 1000 cps in frequency were transcribed onto magnetic tape and presented to the subjects at 80 db (relative to 0.0002 dyne/cm). The first stimulus was always the reference signal. The subjects were instructed to make judgements of longer, equal, or shorter of the second signal with reference to the first. The subjects were allowed a short practice session and were tested in groups. The test procedure including instructions, practice and a short break was approximately one and a half hours in length.

The findings of this study indicate that subjects had greater difficulty discriminating duration of the shorter signals and that the method of presentation, i.e., continuous, warbled or pulsed, did not affect the per cent of correct judgements of duration. A positive time error was found and would seem to have been caused by the lack of counterbalancing of stimuli in the study. Subjects were able to judge durations of stimuli within .28 of a second for warbled stimuli, .48 of a second for continuous stimuli and .51 of a second for pulsed stimuli. Thus judgements of duration were most easily made with warbled stimuli.

Conclusions

Within the experimental framework of this investigation the following conclusions seem to be in order.

1. None of the three methods of presentation facilitated the per cent of correct judgements of duration. That is, the subjects seem to make as many correct judgements of duration for the continu-

ous stimuli as for the warbled and pulsed stimuli.

2. Subjects tend to overestimate the duration of a constant reference tone, thus presenting results skewed by a positive time error.

3. Subjects had greater difficulty perceiving duration of the shorter auditory stimuli.

4. The duration of the auditory stimulus which was necessary for judgements of difference to be made, varies with the method of presentation, i.e., continuous, warbled or pulsed.

5. There is a tendency to use some method of counting to time the duration of signals.

6. It would appear that stimuli used in psychophysical methods of constant stimuli should be counterbalanced.

Implications for Future Research

This study has reported several tendencies regarding the perception of duration of auditory stimuli. There is as yet a great deal of information to be gathered on this subject. This study has in reality been a pilot study with many questions remaining unanswered. A few which might be considered in future research are:

1. What effect would a larger time duration of test stimuli have on the perception of duration of an auditory stimulus?

2. What is the duration necessary to obtain 100 per cent correct responses in judgements of duration?

3. What effect does intensity have on perception of duration of an auditory stimulus?

4. How much does practice effect the judgements of duration?

Continued research in this area would add valuable information to an area of knowledge in the field of Speech and Hearing Science and Acoustics that has not as yet been fully explored.

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APPENDICES

APPENDIX A

Table 4. Random order of presentation of test stimuli on the original test tape.

1. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 6.6 seconds
2. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.0 seconds
3. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.6 seconds
4. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.6 seconds
5. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 6.8 seconds
6. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.8 seconds
7. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.2 seconds
8. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.8 seconds
9. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.0 seconds
10. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 8.4 seconds
11. 1000 cps Continuous 7.6 seconds - 1000 cps Misrecorded
12. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.3 seconds
13. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.0 seconds
14. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.4 seconds
15. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.5 seconds
16. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 8.4 seconds
17. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.6 seconds
18. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.8 seconds
19. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.4 seconds
20. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.2 seconds
21. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.9 seconds
22. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 8.6 seconds
23. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 6.6 seconds
24. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 6.7 seconds
25. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 8.0 seconds
26. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.8 seconds
27. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.8 seconds
28. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 8.6 seconds
29. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.8 seconds
30. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 8.4 seconds
31. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 8.4 seconds
32. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 6.8 seconds
33. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.6 seconds
34. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.2 seconds
35. 1000 cps Continuous 7.6 seconds - 1000 cps Warbled 7.0 seconds
36. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 8.5 seconds
37. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 7.9 seconds
38. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.4 seconds
39. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 7.2 seconds
40. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 6.6 seconds
41. 1000 cps Continuous 7.6 seconds - 1000 cps Continuous 6.8 seconds
42. 1000 cps Continuous 7.6 seconds - 1000 cps Pulsed 8.5 seconds
43. 1000 cps Continuous 716 seconds - 1000 cps Warbled 7.2 seconds

APPENDIX A Table 4 -- Continued

44.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	6.5	seconds
45.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.6	seconds
46.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	8.3	seconds
47.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.2	seconds
48.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.4	seconds
49.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.0	seconds
50.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.4	seconds
51.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	8.4	seconds
52.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.2	seconds
53.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.0	seconds
54.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	6.6	seconds
55.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	7.4	seconds
56.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	6.8	seconds
57.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.2	seconds
58.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.0	seconds
59.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	6.6	seconds
60.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.0	seconds
61.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.6	seconds
62.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.8	seconds
63.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	6.8	seconds
64.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.3	seconds
65.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.9	seconds
66.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.6	seconds
67.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.9	seconds
68.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.8	seconds
69.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.3	seconds
70.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.2	seconds
71.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	6.6	seconds
72.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.3	seconds
73.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.4	seconds
74.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	6.7	seconds
75.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.2	seconds
76.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.4	seconds
77.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	7.2	seconds
78.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	8.0	seconds
79.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	8.2	seconds
80.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	7.2	seconds
81.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.2	seconds
82.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsdd	7.8	seconds
83.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	6.8	seconds
84.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.8	seconds
85.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	6.6	seconds
86.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	6.8	seconds
87.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.6	seconds
88.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.4	seconds
89.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	6.6	seconds
90.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.0	seconds
91.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	8.6	seconds
92.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Warbled	7.0	seconds
93.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Continuous	7.6	seconds
94.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.9	seconds
95.	1000 cps	Continuous	7.6	seconds	-	1000	cps	Pulsed	7.9	seconds

APPENDIX A Table 4 - Continued

96.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.0 seconds
97.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 6.2 seconds
98.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 8.4 seconds
99.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.9 seconds
100.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 8.6 seconds
101.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.6 seconds
102.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.0 seconds
103.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 8.6 seconds
104.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.4 seconds
105.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.6 seconds
106.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.2 seconds
107.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.2 seconds
108.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.8 seconds
109.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 6.8 seconds
110.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.0 seconds
111.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 8.2 seconds
112.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.3 seconds
113.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.0 seconds
114.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 8.6 seconds
115.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 6.6 seconds
116.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.3 seconds
117.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.0 seconds
118.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 6.6 seconds
119.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.4 seconds
120.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.0 seconds
121.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 6.7 seconds
122.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.0 seconds
123.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.9 seconds
124.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.6 seconds
125.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.2 seconds
126.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 6.7 seconds
127.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.6 seconds
128.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.2 seconds
129.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 6.6 seconds
130.	1000 cps Continuous 7.6 seconds	-	1000 cps Pulsed 7.1 seconds
131.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.2 seconds
132.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.4 seconds
133.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.8 seconds
134.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.6 seconds
135.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.2 seconds
136.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.2 seconds
137.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 8.2 seconds
138.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 8.2 seconds
139.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 6.8 seconds
140.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 8.6 seconds
141.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.8 seconds
142.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 7.4 seconds
143.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 6.6 seconds
144.	1000 cps Continuous 7.6 seconds	-	1000 cps Continuous 7.6 seconds
145.	1000 cps Continuous 7.6 seconds	-	1000 cps Warbled 8.4 seconds

APPENDIX A - Table 4 Continued

146.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	6.6 seconds
147.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	7.2 seconds
148.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	7.3 seconds
149.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	6.8 seconds
150.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	6.6 seconds
151.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	7.4 seconds
152.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	7.4 seconds
153.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	8.4 seconds
154.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	8.5 seconds
156.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	8.0 seconds
157.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	7.8 seconds
158.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	7.0 seconds
159.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	6.7 seconds
160.	1000 cps Continuous 7.6 seconds -	1000 cps Pulsed	7.3 seconds
161.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	8.4 seconds
162.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	7.6 seconds
163.	1000 cps Continuous 7.6 seconds -	1000 cps Continuous	6.6 seconds
164.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	8.0 seconds
165.	1000 cps Continuous 7.6 seconds -	1000 cps Warbled	8.0 seconds

Practice pairs:

a.	500 cps Continuous 5.0 seconds -	500 cps Continuous	4.0 seconds
b.	500 cps Continuous 5.0 seconds -	500 cps Warbled	6.0 seconds
c.	500 cps Continuous 5.0 seconds -	500 cps Pulsed	5.0 seconds

APPENDIX B

Table 5

Subject Response Sheet

Name: Age: Sex:

Longer - L Equal - E Shorter - S

	L	E	S		L	E	S		L	E	S		L	E	S		L	E	S		L	E	S
a.								No.56				No.86				No.116				No.146			
b.								57				87				117				147			
c.				No.28				58				88				118				148			
No.1				No.29				59				89				119				149			
No.2				No.30				60				90				120				150			
No.3				No.31				61				91				121				151			
No.4				No.32				62				92				122				152			
No.5				No.33				63				93				123				154			
No.6				No.34				64				94				124				155			
No.7				No.35				65				95				125				156			
No.8				No.36				66				96				126				157			
No.9				No.37				67				97				127				157			
No.10				No.38				68				98				128				158			

Name: Age: Sex:

Longer - L Equal - E Shorter - S

	L	E	S		L	E	S		L	E	S		L	E	S		L	E	S		L	E	S
No.11				No.39				69				99				129				159			
No.12				No.40				70				100				130				160			
No.13				No.41				71				101				131				161			
No.14				No.42				72				102				132				162			
No.15				No.43				73				103				133				163			
No.16				No.44				74				104				134				164			
No.17				No.45				75				105				135				165			
No.18				No.46				76				106				136				166			
No.19				No.47				77				107				137				167			
No.20				No.48				78				108				138				168			
No.21				No.49				79				109				139				169			
No.22				No.50				80				110				140				170			
No.23				No.51				81				111				141				171			
No.24				No.52				82				112				142				172			
No.25				No.53				83				113				143				173			
No.26				No.54				84				114				144				174			
No.27				No.55				85				115				145				175			

APPENDIX C

Table 6

Raw Scores - Continuous, Warbled and Pulsed Data

APPENDIX C

Raw Scores - Continuous Data

Time	Judgements Longer	 Equal	 Shorter
6.6	19	33	68*
6.8	22	41	62*
7.0	27	47	51*
7.2	39	39	46*
7.4	37	56	30*
7.6	49	54*	22
7.8	58*	49	19
8.0	88*	31	6
8.2	67*	35	23
8.4	106*	13	5
8.6	111*	11	3

Raw Scores - Warbled Data

6.6	10	26	88*
6.8	18	46	61*
7.0	28	42	79*
7.2	17	51	57*
7.4	42	45	38*
7.6	45	48*	32
7.8	59*	36	28
8.0	58*	27	16
8.2	79*	34	13
8.4	88*	29	8
8.6	105*	17	3

* Correct responses

APPENDIX C - Continued

Raw Scores - Pulsed Data

Time	Judgements Longer	Equal	Shorter
6.2	3	5	17*
6.5	5	4	16*
6.6	12	29	84*
6.7	18	39	69*
7.0	19	20	36*
7.1	9	8	8*
7.2	25	31	44*
7.3	73	60	66*
7.4	5	9	11*
7.5	8	10	7*
7.6	12	10*	3
7.7	12*	7	6
7.8	49*	32	19
7.9	104*	48	23
8.2	17*	5	3
8.3	11*	8	6
8.4	68*	24	7
8.5	54*	15	7
8.6	41*	6	3

* Correct responses