THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS UPON THE REPRODUCTION OF TEMPORAL INTERVALS BY SENSORI-NEURAL HEARING IMPAIRED SUBJECTS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

Roy Elden Hartbauer

1967

THESIS

This is to certify that the

thesis entitled

THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS
UPON THE REPRODUCTION OF TEMPORAL INTERVALS
BY SENSORI-NEURAL HEARING IMPAIRED SUBJECTS

presented by

Roy Elden Hartbauer

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Speech

Major professor

Date February 13, 1967

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ABSTRACT

THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS
UPON THE REPRODUCTION OF TEMPORAL INTERVALS
BY SENSORI-NEURAL HEARING IMPAIRED SUBJECTS

By Roy Elden Hartbauer

The study of time and the perception of it has occupied the attention of scientists for many years. Both objective and subjective research has been done on time perception of persons with normal hearing with somewhat contradictory findings.

The purpose of this study was to investigate the effects of duration, frequency, and loudness upon the ability of sensori-neural hearing impaired subjects to reproduce temporal intervals. Tones of 500, 1000, and 2000 cycles per second were presented at 60, 70, and 80 phon levels for 1, 5, and 9 seconds. Each of the 27 possible combinations of these parameters was placed in random order on magnetic recording tape and presented ten times randomly to each of the five subjects who sustained a mild sensori-neural hearing loss. The psychophysical method of reproduction was employed. Each subject attempted to reproduce the duration of the stimuli by depressing a telegraph key. During the attempt he heard again a sound of the same frequency and intensity as the stimulus sound.

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The ratio, $\frac{\Delta T}{T}$, to be used in the analysis, was computed by dividing the difference-time (the difference between the stimulus duration and the response duration) by the actual duration of the stimulus. The subject's score was the mean of 10 reproductions for each of the 27 combinations.

It was ascertained by the F-Max test computations that there was a lack of homogeneity of variance for some of the parameters. The results, however, did not preclude the possibility of treating the data by an analysis of variance. It was found that the only variable that affected the reproduction was duration. Specifically, there were significant differences between the pairs of durations of 1 and 5 seconds, 1 and 9 seconds, and 5 and 9 seconds. No effect was found for the frequency and loudness variables. There were no interactions between or among the three parameters.

On the basis of these results it was concluded that within the limits of this study, reproduction of temporal intervals by sensori-neural hearing impaired subjects _is_ affected by the duration of the stimulus. One-second stimuli are overestimated, whereas five- and nine-second stimuli are slightly underestimated. Manipulation of the frequency and loudness parameters did not affect the ability of sensor

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of sensori-neural hearing impaired subjects to reproduce the duration of stimuli.

Subjects with sensori-neural hearing impairments perform similarly to those with normal hearing in the reproduction of the duration of acoustic stimuli.

Recommendations for further research were made on the basis of the results of this study.

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THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS UPON THE REPRODUCTION OF TEMPORAL INTERVALS BY SENSORI-NEURAL HEARING IMPAIRED SUBJECTS

by

Roy Elden Hartbauer

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Speech

1967

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CHAPTER I

INTRODUCTION

The study of time existed before the study of the problems of the acoustically handicapped. The earliest references to man reveal his concern over the nature of time, and the confusion and apparent contradictions over its passage and measurement. The individuality of man has added to the problem. Each person, from his peculiar discipline, views the study of time in a unique way. The work-a-day man sees the time-clock, the athlete sees time as a competitor, the physicist and the astronomer see it as a measuring device, and the philosopher is interested in the nature of time. Gilliland, Hofeld, and Eckstrand[1] point out that the psychologist is interested in the response of people to time. What people do with time is a concern of the sociologist.

Fraisse[2] states that philosophers studying the

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[1]A. R. Gilliland, Jerry Hofeld, and Gordon Eckstrand, "Studies in Time Perception," Psychological Bulletin, XLIII (March, 1946), p. 162.

[2]Paul Fraisse, The Psychology of Time, Trans, Jennifer Leith (New York: Harper and Row, Publishers, 1963), p. 3.

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origin of the idea of time have concluded that the perception of time comes from awareness of change. He asks: What changes, our sensations or our thoughts? The answer to this question differs, depending upon the sensory facilities of the person who is to experience time.

Apart from the sensation of time, the mechanical or rhythmical passing of time has been well detailed by natural phenomena and the invented devices of man. The natural measurement systems mark the yearly cycle by the earth's rotation around the sun, the monthly cycle by the rotation of the moon around the earth, for those of a religious bent the Sabbath cycle by the passing of seven days, and the daily cycle by the earth's rotation on its axis.

It should be noted, as pointed out by Bell and Bell,[3] that the wobbling of the earth on its axis as it travels in its slightly eliptical orbit around the sun, causes some uncertainties of the rotational cycles.

The invented devices of man, such as the clock in its myriad forms and the calendar, are geared to coincide with the markings of the natural phenomena and to divide it into stated segments, such as minutes and seconds. Since

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[3]Thelma Harrington Bell and Corydon Bell, The Riddle of Time (New York: The Viking Press, 1963), pp. 73-74.

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1949, ammonia clocks have been employed by the Bureau of Standards which have a calculated error of only two to four parts in one billion. At the Massachusetts Institute of Technology, Zacharias[4] developed a clock which makes use of the vibrations of cesium atoms as a master governor. Both the nucleus and the outermost electron of the cesium atom behave like minute spinning magnets, each in the force field of the other. Zacharias has calculated that had his invention been "ticking away" since the time of Christ, it would now be only one-half second fast or slow.

With these mechanical devices the results are the same regardless of who operates the equipment. The interpretation of the readings is essentially identical. On the other hand, psychological measurements of time differ, for here time exists subjectively. Sturt[5] suggests that time is a "concept which is built up through individual and racial experience."

Early man measured time in terms of events and/or tasks. According to the Biblical record, time was measured

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[4] Ibid., p. 70.

[5] Mary Sturt, The Psychology of Time (New York: Harcourt Brace, and Company, 1925), p. 1.

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by "the evening and the morning were the first day."[6] Cohen[7] points out that today primitive people customarily measure time in terms of social events and tasks, not in units of duration.

Experimental factors, the tempo of life, the perspective of the proximity of the event to the present, and personal adaptability bespeak that many individual "times" exist as separate subjective entities. The effects of the contents of the intervals between two events, as well as the effects of the events themselves, influence the perception of time. Bell and Bell[8] note that the metabolic rate of the race, society, and the individual influences the perception of the passage of time. It appears that the interval must be filled with interesting, pleasant, or amusing activities and that little attention must be given to its passage for time to seem short.[9]

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[6]Genesis 1:15.

[7]John Cohen, "The Experience of Time," Acta Psychologica, X (1954), p. 211.

[8]Bell and Bell, op. cit., Chapter 6.

[9]Marianne Frankenhaeuser, Estimation of Time (Stockholm: Almquist and Wiksell, 1959), pp. 14-15.

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1965), pp.

Within the limits of human experience, Sturt[10] has noted that there are great differences in the power to perceive time and to deal with temporal ideas. Furthermore, within each person is the existence of many individual subjective times. Some of these are adjusted to synchronize with the times of others to facilitate man's co-existence with his fellow man.

With the focus of attention directed to the problem of the acoustically handicapped and his complaint that life seems to lose its on-going character,[11] the questions arise: "Are there some elements of sound which affect man's perception of time?" "Can some element be isolated as of primary necessity for the accurate and/or consistent perception of the duration of filled intervals?"

Attention is placed, therefore, on the interdigitating of concerns for the passing of time as a subjective entity, the reception of auditory stimuli to influence times passing, and the distortion of that perception by the altering of the reception of the auditory stimuli as experienced

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[10]Sturt, op. cit., p. 10.

[11]I. J. Hirsh, R. E. Bilger, and B. H. Deatherage, "The Effect of Auditory and Visual Background on Apparent Duration," American Journal of Psychology, LXIX (December, 1965), pp. 561-574.

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PURPOSE OF THE STUDY

The purpose of the study was to determine the effects of sensory-neural hearing loss on the perception of the duration of pure tone stimuli as a function of duration, frequency, and loudness. Deal[12] found that duration was the only one of these variables that affected temporal perception in persons with normal hearing.

The questions asked at the outset were as follows:

1. Does the duration of a tone affect the ability of a person with a sensori-neural hearing impairment to reproduce a time interval?

2. Does the loudness of a tone affect the ability of a person with a sensori-neural hearing impairment to reproduce a time interval?

3. Does the frequency of a tone affect the ability of a person with a sensori-neural hearing impairment to reproduce a time interval?

4. Are there any interrelationships among loudness, frequency, and duration that affect the ability of a person with a sensori-neural hearing impairment to reproduce a time interval?

In an attempt to answer these questions, the

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[12]Leo V. Deal, "The Effects of Duration, Frequency, and Loudness Upon the Reproduction of Temporal Intervals," (Unpublished Ph. D. dissertation, Department of Speech, Michigan State University, 1965).

following null hypotheses were formulated for testing:

1. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 1 second, 5 seconds, and 9 seconds.

2. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 500 cps, 1000 cps, and 2000 cps.

3. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 60 phons, 70 phons, and 80 phons.

4. There is no significant interaction between duration and frequency in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

5. There is no significant interaction between duration and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

6. There is no significant interaction between frequency and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

7. There is no significant interaction among duration, frequency, and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

IMPORTANCE OF THE STUDY

One of the concerns of the persons working in habilitation or rehabilitation of the hearing impaired is in ascertaining what the hearing impaired person can hear as well as

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well as what he cannot hear. Knowledge of the hearing ability largely dictates the steps to be detailed in compensating for the handicap.

Many studies have dealt with thresholds for auditory stimuli in normal hearing persons. Still other research has been concerned with the thresholds of persons with sensori-neural hearing impairments. There have not been, however, studies dealing with the perception of the duration of auditory stimuli in persons with sensori-neural hearing impairments. There must be a discovery of the conditions that give rise to variations in the experience of time to ascertain a causal analysis of time perception.[13] This study is a step in ascertaining whether or not any of the parameters of duration, frequency, and intensity are causally related to perception of duration. The findings may have important implications for further research, clinical audiometry, and habilitation or rehabilitation procedures.

DEFINITIONS

Definitions of terms that are commonly used in reports of research on time and in this discussion follow:

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[13]Alden O. Weber, "Estimation of Time," Psychological Bulletin, XXX (March, 1933), p. 235.

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Time. In this paper the term "time" will be considered as a measured duration employed by the experimenter and reproduced by each subject.

Duration. The definition of "duration" used in this study is that period of time during which anything lasts.

Frequency. For this study the term "frequency" refers to the number of oscillations per unit of time of the sound vibrator, expressed in cycles per second.

Loudness. In this paper the term "loudness" refers to the sensation level of auditory stimuli. The unit of measure is the phon, defined as the intensity required to produce the sensation of equal loudness to a 1000 cps tone of a specific intensity. The phon and the decibel are by definition the same at the frequency of 1000 cps.[14]

Indifference interval. For this study the indifference interval will be the same as for the study by Deal:[15] "taken as the point which the ratio of the average difference-point divided by the actual duration is equal to zero. It is the point where overestimation changes to underestimation."

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[14]Hayes A. Newby, Audiology (New York: Appleton-Century-Crofts, 1964), pp. 166-167.

[15]Deal, op. cit., p. 16.

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Time-order errors. As with the indifference interval, the time-order errors will have different meaning when different psychophysical methods are employed. The definition by Woodrow is used for this paper: "The effect due to the temporal order of presentation of the standard and the variable."[16] *Positive error* will be used when the stimulus interval is *over*estimated, *i.e.* when the subject's reproduction is too long. *Negative error* will be used when the stimulus interval is *under*estimated, *i.e.* when the subject's reproduction is too short.

Sensori-neural hearing impairment. For the purpose of this study, the term "sensori-neural hearing impairment" will refer to any shift of greater than 15 decibels (re. audiometric zero) of thresholds for pure tone sounds, 500, 1000 and 2000 cycles per second, due to lesions in the auditory tract central to the oval window of the cochlea. There will be a negligible difference between the air conduction and bone conduction thresholds which could indicate a conductive element in the hearing impairment.

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[16] Herbert Woodrow, "Time Perception," *Handbook of Experimental Psychology*, ed. S. S. Stevens (New York: John Wiley and Sons, Inc., 1951), p. 1225.

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CHAPTER II

REVIEW OF BACKGROUND LITERATURE

INTRODUCTION

While some researchers have approached the study of time perception from an empirical standpoint by direct experience or observation alone, others have approached it experimentally. Both have arrived at theories of the perception of time. The diversity of approach has resulted in a diversity of theories and numerous apparent contradictions. It is evident that the perception of time is not a constant thing.

Excellent reviews of literature on time perception include those by Gilliland and Humphreys,[17] Triplett,[18]

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[17] A. R. Gilliland and Dorothy Humphreys, "Age, Sex, Method, and Interval as Variables in Time Estimates," Journal of Genetic Psychology, LXIII (September, 1943), pp. 123-130.

[18] Dorothy Triplett, "The Relation Between the Physical Pattern and the Reproduction of Short Temporal Intervals: A Study in the Perception of Filled and Unfilled Time," Psychological Monographs, XLI (1931), pp. 201-265.

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Fraisse,[19] Woodrow,[20] and Weber.[21]

The study of the nature of time, which is a concern of philosophy, also became a concern of psychology. With both disciplines, research on time study moved to the laboratory during the nineteenth century, where the concerns of early research included the effects of the content of the interval, the application of Weber's Law, and constant errors.[22] Research on these gave bases for other approaches used in the study of time.

THEORIES OF TIME PERCEPTION

One of the earliest theories of time perception suggested a "time sense."[23] This included an internal, i.e. biological or physiological, clock mechanism. Some of the later theorists maintained that time perception is some phase of the "self" which is uniquely the individual.

Different forms of temporal experience suggested by

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[19]Fraisse, op. cit., pp. 1-343.

[20]Woodrow, "Time Perception," pp. 1224-1236.

[21]Weber, op. cit., pp. 232-252.

[22]Fraisse, op. cit., pp. 5-9.

[23]Gilliland, Hofeld, and Eckstrand, op. cit., pp. 164-172.

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Cohen[24] are: duration; sequence; pastness, the feeling of what has gone before; nostalgia, the changing effect when experiences recede into the past; sinceness, the feeling that time has elapsed since the occurence of an event; and orientation toward the future. It must be noted that time perception varies within an individual as well as varying from one person to another.[25]

Theories of time perception seem to fall into five primary divisions:

1. Time is perceived by a central nervous system mechanism.
2. A temporal clock mechanism provides a "time sense."
3. Time is perceived by bodily rhythms.
4. The amount of change determines the perception of time.
5. Duration has a "unity of organization."[26]

Central Nervous System Mechanisms. Fraisse gives a comprehensive review of the theories that explain the judgment of duration on the basis of the brain mechanism.[27] Typical of these theories is this one by James: "...each

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[24]John Cohen, "The Experience of Time," Acta Psychologica, X (1954), pp. 208-209.

[25]Sturt, op. cit., p. 147.

[26]Deal, op. cit., p. 147.

[27]Fraisse, op. cit., pp. 95-105.

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stimulus leaves some latent activity behind it which only gradually passes away.."[28] That is to say, there is some hold-over from the preceding stimulus while we are responding to the present stimulus. Especially under certain circumstances and conditions, some of these processes have a more rapid decay time than do others.

In support of this type of theory, Frankenhaeuser[29] suggests that the second of two successively presented sounds of equal intervals will be judged as being longer because of the fading trace of the first one. This would be particularly true with a short interval between the two stimulus sounds.

The electrical gradient in the brain field determines the physiological process of successive comparison, according to Postman.[30] He states that the excitation of a sense end-organ causes a disturbance of equilibrium in the brain field. This, in turn, leaves a trace, the aftereffects of which will in time fade or "sink," and the

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[28]William James, The Principles of Psychology (New York: Dover Publications, Inc., 1950), pp. 634-635.

[29]Frankenhaeuser, op. cit., p. 19.

[30]Leo Postman, "Time-Error as a Function of the Method of Experimentation," American Journal of Psychology, LX (January, 1947), pp. 101-108.

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longer the interval between the stimuli, the less residual trace there will be to affect the second stimulus.[31]

Experiments by Nichols[32] seem to support the hypothesis that time is perceived by memory images. His results emphasize that memory images depend upon certain rhythmic habit processes of our nervous system and our bodily organism. Nichols does not identify any specific part of the brain as responsible for the memory of these rhythmic habits.

As an example of those advocates of the memory-image theory who do not agree with others, Angell[33] believes that this theory has had a definitely negative influence on psychological research. Still other researchers, e.g. Edgell,[34] could claim no experimental results to support this theory.

A slightly different approach was taken by Creelman. He hypothesized that perhaps "a 'counting mechanism,' a

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[31]Frankenhaeuser, op. cit., p. 19.

[32]Herbert Nichols, "The Psychology of Time," American Journal of Psychology, IV (April, 1891), pp. 102-107.

[33]F. Angell, "Discrimination of Clangs for Different Intervals of Time," American Journal of Psychology, XII (October, 1909), p. 79.

[34]Beatrice Edgell, "On Time Judgment," American Journal of Psychology, LLV (July-October, 1903), pp. 169-170.

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simple accumulator, could store neural pulses in reverberatory circuits, or for that matter, store an electrical charge due to a chemical process."[35]

The Temporal Clock Mechanism. As researchers have attempted to explain time perception, they have speculated that there may be an internal clock that would be a time-sense as surely as there are other senses even though, as presented in Mach's theory, time perception is a general sense while the others are specific senses. It employs the specific senses.[36]

Following their noting that the midbrain controls all the main periodic rhythms such as hunger, thirst, sleep, and sex needs, some researchers have considered the midbrain as the temporal clock. It may be possible, therefore, that these vegetative processes may act as a basis for the experience of time.[37]

In light of recent research, few persons still

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[35]Carlton Douglas Creelman, "Human Discrimination of Auditory Durations" (Unpublished Ph. D. dissertation, Department of Psychology, University of Michigan, 1960), p. 47.

[36]Fraisse, op. cit., pp. 80-81.

[37]Ibid., p. 171.

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maintain that there is a special "time sense;" that is, that time is something which is experienced, or that a person is able to relate himself to clock time. Bartley has hypothesized that the body processes and sensory mechanisms make this possible.[38]

Bodily rhythms. Noting that animals seem to have some ability, not based on any symbolic device nor intellectual process, to estimate duration, Fraisse[39] believes that man is capable of estimating time on a biological level. It may be, he states, that the biological influences work with the mind to permit surprising accuracy of judgments.

MacDougall,[40] opposing the special time-sense theory, points out that subjective standards of measurement are dependent upon physiological changes. He suggests that variations in the tension of sense organs form the basis for the judgment of short durations while the rhythms of respiration determine the estimates of longer duration.

Nichols,[41] who does not accept the bodily rhythms

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[38]S. Howard Bartley, Principles of Perception (New York: Harper and Brothers, 1958), p. 69.

[39]Fraisse, op. cit., p. 62-63.

[40]Robert MacDougall, "Rhythm, Time and Numbers," American Journal of Psychology, XIII (January, 1902), p. 88.

[41]Nichols, op. cit., p. 106.

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theory, points out that breathing, pulse-beat, and leg swing have all been suggested as factors in the estimation of duration. He sees no reason why any one unconscious process should dominate as a standard more than another. Neither did Renshaw's[42] experimental results support a theory of time perception based on kinesthetic cues. His subjects, who sat still and alert, made better judgments than did those who made any physical movement.

Amount of Change. It has been advanced by some that changes in both bodily processes and external stimuli serve as cues for the perception of duration.[43] Sturt[44] believes that we experience duration indirectly, as opposed to the way we sense taste, touch, or smell.

Fraisse believes that the body, under the influence of physiological changes, becomes a physiological clock to furnish cues for time perception. On the premise that perception of duration is based on successive changes, Fraisse

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[42]Samuel Renshaw, "An Experimental Comparison of the Production, and Auditory Discrimination by Absolute Impression of a Constant Tempo," Psychological Bulletin, XXIX (November, 1932), p. 659.

[43]Bartley, op. cit., p. 69.

[44]Sturt, op. cit., p. 8.

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stated the law, "Any factor which contributes toward an increase or decrease in the number of changes observed has the effect of lengthening or shortening the apparent duration."[45]

It appears that even attempts to blot from our awareness any conscious method of marking time do not eliminate the influence of physiological or environmental changes. Discussing this, James indicated that the numbers and types of changes, that is the stimulus duration content, dictate the perception.[46]

The Concept of Unity. Boring[47] suggests that because some physiological events must take place before the reporting of duration, it cannot be an instantaneous experience. He maintains that there can be no immediate experience of duration but that there must be a continuity of duration.

This brings up the point as to how much time must pass before it can be said that one event has ended and another has begun. Sturt[48] notes that there seems to be an

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[45]Fraisse, op. cit., pp. 15-17.

[46]James, op. cit., p. 620.

[47]Edwin G. Boring, "Temporal Perception and Operationism," American Journal of Psychology, XLVII (July, 1936), p. 521.

[48]Sturt, op. cit., p. 17.

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intuitive duration that man can grasp as a whole. Fraisse[49] says that the limit of a _perceived present_ is approximately five seconds. He suggests that an event that lasts for longer than five seconds ceases to be a singular unit but becomes the first of a series of events.

The _spacious present_ may be anywhere from 3.6 to 12 seconds, according to research discussed by James.[50] Woodrow,[51] referring to a _temporal span of attention_, that time over which stimuli may be spread and still be perceived as present, suggests, rather than specifies, that there are maximal and minimal durations for this temporal span. Kawalski[52] notes from research that a minimum of 1.5 seconds must elapse while Woodrow[53] believes that the maximum limit of the "psychological present" is about six seconds. After summarizing several investigations, however, he concludes that there is a range of unity which probably lies between

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[49]Fraisse, _op. cit._, pp. 84-93.

[50]James, _op. cit._, pp. 612-613.

[51]Woodrow, "Time Perception," p. 1230.

[52]Walter Kawalski, "The Effect of Delay Upon the Duplication of Short Temporal Intervals," _Journal of Experimental Psychology_, XXXIII (September, 1943), p. 239.

[53]Woodrow, "Time Perception," p. 1230.

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DEVELOPMENT OF THE CONCEPT OF TIME

Persons who accept literally the Scriptural record of the origin of man, believe that man was aware of time and its passing from the time of his creation. The record of the Divine creation of man, as presented in Genesis[54] concludes with: "and the evening and the morning were the sixth day." According to the Scriptural account, the marking of time was impressed upon the mind as a permanent, irrevocable memorial by the marking of the Sabbath.[55]

The passing of time and the seasons were also to be noted through natural phenomena.[56] These phenomena were to be the manifestations in the sun, moon, and stars.

Those who do not accept the Scriptural account of creation as a record of fact, also agree, however, that man's first concern over time was due to his observations in natural phenomena. Primitive man, according to Bell and Bell,[57] became aware of time by noting the rhythmical

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[54]Genesis 1:26-31.

[55]Genesis 2:1-3.

[56]Genesis 1:14-18.

[57]Bell and Bell, op. cit., pp. 16-17.

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changes both in nature and in himself. The next step of discernment was that time could be classified as present, past, and future. Fraisse[58] proposed that the beginning of the notion of time as a vital factor comes from the experience of successions. Some of these are periodic, some are continuous, and some are interwoven renewals and relatively permanent.

Sturt[59] theorizes that three primitive experiences led to the development of a time concept: (1) the apprehension of an event as having duration in time; (2) the apprehension that one event has occurred before, or will occur after another; and (3) the experience of two things occurring simultaneously.

Attention is directed next to studies of the development of the time concept by children. There appear to be some perceptions of time which are the same for children and adults. Both have the same feeling that time spent waiting is too long and that time spent in effort is never ending.[60] As noted by Fraisse,[61] children first grasp a

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[58] Fraisse, op. cit., p. 1.

[59] Sturt, op. cit., p. 1.

[60] Fraisse, op. cit., p. 328.

[61] Ibid., p. 180.

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concept of the rhythms of everyday experience; next, they organize time sequences; then comprehend the adult measures of time. Fraisse believes that specific training improves the ability of children to estimate duration. The ages for the development of time concepts seem to be about four years for the first awareness and about thirteen to fourteen years for it to reach the adult level.[62] Smythe and Goldstone[63] concur on this.

It is of interest to note that with children, the learning of the concept of time goes from specific to general.[64] Yet another influence, as mentioned by Harrison[65] after her working with a selected vocabulary, is that the development of language plays an important part in the development of time perception.

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[62]E. C. Oakden and Mary Sturt, "The Development of the Knowledge of Time in Children," British Journal of Psychology, XXI (April, 1922), pp. 309-336.

[63]Elizabeth J. Smythe and Sanford Goldstone, "The Time Sense: A Normative, Genetic Study of the Development of Time Perception," Perceptual and Motor Skills, VII (March, 1957), pp. 45-59.

[64]Louise Bates Ames, "The Development of the Sense of Time in the Young Child," Journal of Genetic Psychology, LXVIII (March, 1946), pp. 97-125.

[65]M. Lucile Harrison, "The Nature and Development of Concepts of Time Among Children," Elementary School Journal, XXIV (March, 1934), pp. 507-514.

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PROBLEMS IN THE STUDY OF TIME PERCEPTION

In the consideration of psychophysical problems in the research on time perception one encounters these: (1) Weber's Law, (2) time-order error, (3) indifference interval, and (4) methods used in judging.

Weber's Law. As a formula Weber's law reads $\frac{\Delta S}{S} = C$. is the differential increase in a stimulus that produces a just noticeable difference (j.n.d.); that is, the incremental ratio of the just noticeable difference is a constant (c) over the entire range of suprathreshold stimuli.[66] Fechner attempted to apply the law to the perception of time and secured varying results. Since Nichols[67] concluded in 1890 that Weber's Law does not apply to temporal intervals, Mencke,[68] Small and Campbell,[69] and

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[66]Franklin M. Henry, "Discrimination of the Duration of Sound," Journal of Experimental Psychology, XXXVIII (December, 1948), pp. 734-743.

[67]Nichols, op. cit., p. 112.

[68]Eugene Oliver Mencke, "Monaurel Differential Sensitivity for Short Stimulus Duration," Dissertation Abstracts, XXIV (August, 1963), p. 854.

[69]Arnold M. Small, Jr., and Richard A. Campbell, "Temporal Differential Sensitivity for Auditory Stimuli," American Journal of Psychology, LXXV (September, 1962), p. 404.

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Edgell,[70] have agreed with his findings.

In 1940, Gilliland[71] seemed to find, conversely, that Weber's law was applicable for durations from 4-27 seconds. Henry observed that the Weber ratio increased sharply with his shortest time of 32 and 47 milliseconds and that it had a slight tendency to decrease somewhat linearly as the duration was increased.[72] In a later study he noted that the Weber ratio was slightly higher for his lowest intensity level of 20 dB.[73] In still another experiment, he noted that the Weber ratio tended to be higher for low frequencies. Creelman reported that only in some very special experimental circumstances did Weber's law hold approximately for duration discrimination.[74]

Time-order Error. Frankenhaeuser has succinctly stated the time-order concept on psychophysics as "the difference between subjective and objective equality induced

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[70]Edgell, op. cit., p. 171.

[71]A. R. Gilliland, "Some Factors in Estimating Short Time Intervals," Journal of Experimental Psychology, XXVII (September, 1940), p. 255.

[72]Henry, op. cit., p. 737.

[73]Ibid., p. 739.

[74]Creelman, "Human Discrimination of Auditory Duration," p. 592.

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by the order of presentation..." She illustrates: "When, for example, two objectively equal stimuli are compared, the first stimulus in the pair will usually seem less than the second. In this case the time-order error is negative, whereas when the first stimulus is judged the greater, the error is positive." Experimental data show that the negative errors occur much more frequently.[75]

As the time interval between the two stimuli is increased, the size of the negative time-error seems to increase. Conversely, when the interstimulus interval is decreased, the positive time-error tends to decrease.[76]

Needham[77] made an important contribution by noting that the time-order error is small or absent with an interval of approximately three seconds. The time-order error increased negatively with intervals between 3-12 seconds and the error is positive with interstimuli intervals of 0-3 seconds.

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[75]Frankenhaeuser, loc. cit.

[76]George Kruezer, "The Neurological Level of the Factors Underlying Time-Errors," American Journal of Psychology, LI (January, 1938), p. 18.

[77]J. Garton Needham, "The Time-Error as a Function of Continued Experimentation," American Journal of Psychology, XLVI (October, 1934), p. 558.

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Indifference Interval. Woodrow[78] presents a comprehensive survey of the literature on the indifference interval. There are some intervals that are neither overestimated nor underestimated; this intermediate length is called the indifference interval. It is that point where the time-order error is zero.

Woodrow[79] does not agree with the generally held view that there is a human tendency to overestimate short intervals and underestimate longer intervals. He points out that a short interval may be overestimated if it is the second one. Thus, any constant error is due only to the order of presentation.

Stevens,[80] after finding an indifference interval between .53 and .87 second, pointed out that his subjects tended to add to long intervals and subtract from short intervals. His results differ greatly from those secured by other researchers.

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[78]Woodrow, "The Temporal Indifference Interval Determined by the Method of Mean Error," Journal of Experimental Psychology, XVII (April, 1934), pp. 167-188.

[79]Woodrow, "The Reproduction of Temporal Intervals," Journal of Experimental Psychology, XIII (December, 1930), pp. 473-474.

[80]Lewis T. Stevens, "On the Time Sense," Mind, XI (July, 1886), pp. 393-404.

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Even though indifference intervals from .35 to 5.0 seconds have been reported by investigators, intervals of 0.5 to 0.7 second have been observed by the majority.[81]

In attempting to answer the question as to why researchers obtain such different findings, Stott[82] postulated that the results depend in part on the experience of the subjects. A judgment of an experience is made against what we expect it to be. We judge against the average. Subjects will tend to underestimate durations that are above the average. This agrees with Fraisse's[83] statement that the development of a central tendency is one of the most important conditions affecting the indifference interval.

It is speculated that different psychophysical methods will result in different indifference intervals. Woodrow[84] supports this by stating that an indifference interval derived by the method of comparison is different from an indifference interval derived by the method of

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[81]Woodrow, "Time Perception," p. 1226.

[82]Leland H. Stott, "The Time-Order Errors in the Discrimination of Short Tonal Durations," Journal of Experimental Psychology, XVIII (December, 1935), pp. 743-744.

[83]Fraisse, op. cit., p. 120-122.

[84]Woodrow, "The Reproduction of Temporal Intervals," pp. 474-475.

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reproduction. Furthermore, he states that there is no single indifference interval valid for all subjects.[85]

<u>Methods Used in Judging</u>. The instructions given their subjects by the researchers have varied from highly structured and minutely detailed to instruction to use any device except a watch. Devices which subjects have used have varied from "just guessed" or "movements of the feet" as reported by Axel,[86] to those reportedly used by the subjects of Alvard and Searle:[87] (1) judged by muscular strain and relaxation, (2) imagined an auditory rhythm, (3) imagined motor movement, and (4) imagined clicks of the key used to present the tones. Gilliland's[88] subjects, when given permission to employ any device they wished to use, resorted to some form of counting. With these subjects, practice by counting reduced the error from 25-30 percent to 5-10 percent.

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[85]Woodrow, "Time Perception," p. 1226.

[86]Robert Axel, "Estimation of Time," <u>Archives of Psychology</u>, XII (November, 1924), pp. 45-46.

[87]Edith A. Alvard and Helen E. Searle, "A Study in the Comparison of Time Intervals," <u>American Journal of Psychology</u>, XVIII, No. 2 (April, 1907), pp. 177-182.

[88]Gilliland, <u>op</u>. <u>cit</u>., pp. 243-255.

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Woodrow's[89,90] experimental subjects, reproducing intervals in an automatic manner, without giving attention to their finger movements, made short reproductions. On the other hand, when the subjects concentrated on their movements, the reproductions were too long.

In contrast to the findings of others, MacDougall[91] found that subjects were more accurate in their estimates while listening passively than when attending to motor movements. From this he judged that motor movements hinder the duration judgments.

PSYCHOPHYSICAL METHODS EMPLOYED IN THE STUDY OF TIME

Several psychophysical methods of research have been employed in seeking the answers to sense perception. As in any field of investigation, some of the methods have been used more than have others.

Method of Reproduction. In the method of reproduction the subject is given either a filled or empty interval.

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[89]Woodrow, "The Reproduction of Temporal Intervals," pp. 473-499.

[90]Woodrow, "Individual Differences in the Reproduction of Temporal Intervals," American Journal of Psychology, XLV (April, 1933), pp. 271-281.

[91]MacDougall, op. cit., pp. 90-91.

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Following this exposure, he is to perform some function which will reproduce the variable (in this case it is the duration) of a sound or silence identical to that of the stimulus.

Spencer,[92] employing a sharp rap to mark the interval, instructed the subject to measure the same length of time with a stop watch. His experience with this shows that the subjects may be aware of distractions, thus causing inordinately short or long responses.

It is evident from Edgell's[93] work that an individual subject will favor a selected interval. Longer intervals are underestimated, and shorter intervals will be overestimated.

Empty intervals of 0.2 to 30.0 seconds bounded by two impact sounds were used by Woodrow.[94] From this project he reported that there seemed to be no universal tendency for underestimation of long, empty intervals nor overestimation of short ones. The subjects seemed to differ

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[92]Lewellyn T. Spencer, "An Experiment in Time Estimation Using Different Interpretations," American Journal of Psychology, XXXII (October, 1921), pp. 557-562.

[93]Edgell, op. cit., pp. 154-174.

[94]Woodrow, "The Reproduction of Temporal Intervals," pp. 473-499.

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from day to day and with change of attitude. It is worthy of attention, however, that shorter intervals were more consistently judged. There was a noticeable increase in variability for durations between 1.5 and 4-6 seconds, and little change in the relative standard deviations for stimuli longer than six seconds.

When Woodrow[95] used the same method, employing intervals from 300 to 4000 milliseconds, he had different groups reproduce different intervals. Eighty-four percent of the subjects made reproductions which were too short for the long ones. By extrapolation he secured an indifference interval of 625.3 milliseconds, which is within the range between 600 and 700 milliseconds where the change from a negative to a positive error appeared.

The effects of extraneous sounds, that is sounds other than the stimulus, were also investigated by Hirsh, Bilger, and Deatherage.[96] They reported that the duration of a response in noise after stimulation in quiet is longer

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[95]Woodrow, "The Temporal Indifference Interval Determined by the Method of Mean Error," pp. 167-188.

[96]I. J. Hirsh, R. C. Bilger, and B. H. Deatherage, "The Effects of Auditory and Visual Background on Apparent Duration," American Journal of Psychology, LXIX (December, 1965), pp. 561-575.

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Still another factor, the time lapse between the end of the stimulus and the beginning of the subject's response, was considered by Kawalski.[97] From his results, he concluded that the delay interval had no appreciable effect, noting, however, that there was a tendency for greater accuracy of estimates with an increase in the delay time.

Of importance to this study is the postulation by Fraisse[98] that the method of reproduction results in less error than does the method of production, which in turn gives a smaller error than does the method of estimation. Attention should be called to the fact that with the method of estimation, the variability from one subject to another and the variability within one subject are the greatest. Kawalski[99] regards the method of reproduction as the best for both accuracy and flexibility.

It should come as no surprise that not all experimenters had findings which agree with Fraisse and Kawalski.

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[97]Kawalski, op. cit., pp. 329-346.

[98]Fraisse, op. cit., pp. 213-214.

[99]Kawalski, op. cit., p. 239.

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The conclusion made by Clausen[100] was that the method of reproduction was not reliable. It seems reasonable that unless all variables are held constant by all researchers for attempts at exact replications, it can hardly be expected that the same data and conclusions will be obtained. The lengths of the stimuli, the lengths of the intervals, the instructions to the subjects, the method of response, and innumerable other variables may alter the results.

Method of Comparison. Many investigators concur that a different entity is being evaluated by the method of comparison than by any other psychophysical method. Some investigators recognize the possibility that a different entity is being evaluated by each of the two major subdivisions of the method of comparison which are: (1) the method of limits, and (2) the constant method.

Two stimuli, a standard one and a variable one, are presented in pairs in the method of limits. The variable stimuli are set at selected equal-steps either preceding or following the standard stimulus. The task of the subject is to judge whether the two stimuli are equal or if

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[100]John Clausen, "An Evaluation of Experimental Methods of Time Judgment," Journal of Experimental Psychology, XL (December, 1950), pp. 756-761.

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Most frequently, in the methods of limits, the standard stimulus is presented first in the pairs and the variable stimuli are presented serially.

Creelman,[101] employing the constant method, ascertained that the detection of difference became easier as the difference between the two stimuli was made larger. As he kept a constant difference time of 0.1 second, he found that as the standard stimulus is increased, the detection of a difference between the two decreased. During another experiment he observed that increased signal voltage permitted better detection of the difference and greater duration of the difference caused poorer difference detection.

At Michigan State University, Shaefor[102] studied the perception of duration using three signals: continuous, warbled, and pulsed. She presented them via the method of constant stimuli. Among her findings were these:

1. A duration difference of at least .28 second was needed for detection of difference for warble tones.

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[101]Creelman, "Human Discrimination of Auditory Duration," p. 26.

[102]Patricia Shaefor, "A Study of the Perception of Duration of Continuous, Warble and Pulsed Signals," (Unpublished M. A. Thesis, Department of Speech, Michigan State University, 1963), pp. 32-33.

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2. A duration difference of at least .48 second was needed for detection of differences for continuous tones.

3. A duration difference of at least .51 second was needed for detection of difference for pulsed tones.

4. Subjects had greater difficulty in discriminating short tones than in discriminating long tones.

5. The second of the two stimuli tended to be judged as the shorter (a positive time-error).

Mencke,[103] using 40, 60, 80, and 100 milliseconds, concluded that the magnitude of the difference limen for short auditory durations depends on the frequency and intensity of the variable stimulus and on the duration of the reference stimulus. Milburn[104] replicated the study with the exception of using durations of 300, 500, and 1000 milliseconds. He suggests that the magnitude of the relative difference limen for pure tone stimuli depends on the duration and sensation of the reference stimuli but does not depend on the frequency.

Method of Estimation. The task of the subject with this psychophysical method is to state verbally how long he

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[103]Mencke, loc. cit.

[104]Braxton Milburn, "Differential Sensitivity to Duration of Monaural Pure-Tone Auditory Stimuli," Dissertation Abstracts, XXIV (December, 1963), p. 2578.

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thinks a stimulus interval (filled or unfilled) has lasted.

Sturt[105] found in her work with durations of seconds and minutes that there was much irregularity in accuracy and in the comparative length of the real and apparent time. She observed no significant tendency of the subjects to overestimate or underestimate the time. Furthermore, practice did not improve the ability of the subjects to be more accurate.

Method of Production. Some researchers believe this is the opposite of the method of estimation, or as Clausen[106] refers to it, the method of verbal estimation. In the method of production the researcher states a certain duration of time, and it is the task of the subject to produce the signal. Particular note should be taken that, with this method, overestimation means that the subject allowed less chronological time to elapse before feeling the stated duration had passed.

Sturt also employed this psychophysical method and with it, too, found a definite tendency to overestimate or underestimate the temporal interval.

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[105]Sturt, op. cit., pp. 93-94.

[106]Clausen, loc. cit.

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Method of Fractionation. In creating scales for various sense modalities, researchers have assigned the subjects the task of producing a signal that is half the standard signal. Employing this in hearing research, the subject may be asked to judge duration, pitch, or loudness. The scale for pitch is mel, and for loudness the scale is phon.

Gregg[107] referred to his unit of duration as "temp" as he constructed a half-time scale and arbitrarily established one second as one temp. He found considerable accuracy in subjects' estimates of half time.

According to Fraisse[108] there is little to be gained from the construction of subjective time scales. He argued that the apparent half of another apparent duration is equal to the true half of the latter.

INDIVIDUAL DIFFERENCES

Sex Differences. Research tends to indicate that estimations of time intervals are less reliable when made by women than by men.

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[107] Lee W. Gregg, "Fractionation of Temporal Intervals," Journal of Experimental Psychology, XLIII (November, 1951), pp. 307-312.

[108] Fraisse, op. cit., p. 145.

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Yerkes and Urban,[109] employing the method of estimation, found that both men and women have tendencies to favor estimates ending in 0 and 5 as well as simple fractions of a minute, with women having the greater tendency.

Yerkes and Urban[110] also found that men slightly overestimated the length of a second and women greatly overestimated it. With intervals from 18 to 108 seconds men generally underestimated slightly, and women greatly overestimated. These researchers ascertained that estimates made by women were more variable and less accurate.

Both Gulliksen[111] and MacDougall[112] obtained similar results; that is, that women overestimated durations and were less accurate.

Males, according to Axel,[113] tend to underestimate durations of time between 15 and 30 seconds. Females, on

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109Robert M. Yerkes and F. M. Urban, "Time Estimation in Its Relations to Sex, Age, and Physiological Rhythms," Harvard Psychological Studies, II (June, 1906), pp. 405-430.

110Ibid.

111Harold Gulliksen, "The Influence of Occupation Upon the Perception of Time," Journal of Experimental Psychology, X (February, 1927), pp. 52-59.

112Robert MacDougall, "Sex Differences in the Sense of Time," Science, XIX (April, 1904), pp. 707-708.

113Axel, op. cit., pp. 30-31.

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More recent research done by Gilliland, Hofeld, and Eckstrand[114] did not secure data to demonstrate this sex difference.

<u>Age Differences</u>. Fraisse[115] discusses two points regarding age differences. One is that there may be a change in biological time with increase in age. There are a number of biological changes that are greater in the young. More work is accomplished by the youth, resulting in time seeming longer. The other point discussed by Fraisse[116] is that the child perceives present experience in terms of the future, or anticipation, whereas the older person gives more attention to the past. Fraisse hypothesizes that man attaches the greater importance to the longer portion of his life. He points out that there is a slow development in the ability to estimate time until a child reaches approximately sixteen years of age. He notes, however, that children seem to grasp the idea of duration at a fairly early age if the method of reproduction is employed. Because a child does not have the ability to use

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[114]Gilliland, Hofeld, and Eckstrand, <u>op</u>. <u>cit</u>., p. 168.

[115]Fraisse, <u>op</u>. <u>cit</u>., p. 236.

[116]<u>Ibid</u>., pp. 181-182.

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actual time measurements in verbal estimates of time, he is more dependent than an adult on what fills the interval.

Axel[117] noted a marked improvement in the time estimation by children between nine and eleven years of age but negligible improvement after age eleven. When he compared boys nine through fourteen with college men, he observed more accuracy and less variability in time estimations by the college men.

Counting seems to be an important cue for time estimation for children as well as for adults. Gilliland and Humphreys[118] noted this in their comparison of adults with fifth grade children. With both the children and the adults the method of reproduction seemed to be best.

Frankenhaeuser[119] points out that while youth is filled with numerous events, life seems to become more automatic, thus changing the perception of the passing of time.

Motivation and Attitude. Sturt[120] believes that time estimates depend on attention. The subject becomes oblivious to the passing of time if attention to it is destroyed.

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[117] Axel, op. cit., pp. 52-66.

[118] Gilliland and Humphreys, op. cit., pp. 125-130.

[119] Frankenhaeuser, op. cit., p. 117.

[120] Sturt, op. cit., pp. 89-92.

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Fraisse[121] notes that if a subject pays much attention to the passing of time, he will likely overestimate its duration. These findings bear out the fact that attention, as much as any factor, influences time perception.

In the first of two studies done by Harton,[122] he noted that his subjects reported that time seemed shorter when they were doing successful activity. In his second study he had one group work one maze and another group work several mazes. Time seemed shorter for the subjects striving for one goal, that is, completing one task, than it did for those subjects striving to complete several tasks.

Nervousness and excitement shorten time judgments and according to Nichols,[123] items which come first in an experimental situation tend to seem shorter.

Mead[124] ascertained that both a greater rate of progress and greater proximity resulted in lower estimates of

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[121] Fraisse, op. cit., pp. 146-147.

[122] John J. Harton, "The Influence of the Degree of Unity of Organization on the Estimation of Time," Journal of General Psychology, XXI (July, 1939), pp. 25-49.

[123] Nichols, op. cit., p. 82.

[124] Robert D. Mead, "Time Estimates as Effected by Motivational Level, Goal Distance, and Rate of Progress," Journal of Experimental Psychology, LXIII (October, 1959), pp. 275-279.

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time.[125]

If a subject is not sufficiently motivated to keep from being distracted, says Fraisse,[126] he may concentrate on the effort involved, thus making time pass more slowly. If the subject is concentrating on the task itself, he is unaware of the passage of time.

According to Woodrow,[127] there can be two attitudes taken in estimating time: objective attitude--the subject concentrates upon the characteristics of the stimulus; and subjective attitude--the subject concentrates only on the experience of duration. His research pointed out that giving maximal attention to the second of two tones resulted in an overestimation of the duration, whereas giving passive attention to the second tone resulted in an underestimation.

Practice Effects. Experimental studies using the *Seashore Measures of Musical Talent* indicate that improvement with practice is often a result of a change in work rather than in perception. Attitude, division of labor,

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[125]Robert D. Mead, "Effects of Motivation and Progress on the Estimation of Longer Time Intervals," *Journal of Experimental Psychology*, LXV (June, 1963), pp. 564-567.

[126]Fraisse, *op. cit.*, p. 220.

[127]Woodrow, "Time Perception," p. 1228.

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tendency to anticipate, laziness, and indifference often influence the work method. Triplett[128] used two groups in her research and found that subjects with a "musical" ability varied less in duration estimations than did the "nonmusical." This seems to indicate that practice does improve the sense of time.

Stott[129] found that previous experience in comparing durations was an important factor in ascertaining time-order error and indifference interval. The time-order indifference point for naive listeners was 0.92 second; while for experienced listeners it was between 1.6 and 2.0 seconds.

PERCEPTION OF TIME BY HEARING IMPAIRED SUBJECTS

A survey of literature for studies done on the perception of time by subjects with any type of hearing impairment reveals that nothing has been done, *per se*. The researcher investigated books and periodicals in speech and hearing, psychoacoustics, psychology, physiology, and neurology. Personal conversations and personal correspondence with some leading research scientists in the field

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[128]Triplett, *op. cit.*, pp. 260-263.

[129]Leland H. Stott, "Time-Order Errors in the Discrimination of Short Tonal Intervals," *Journal of Experimental Psychology*, XVIII, No. 6 (December, 1935), pp. 741-766.

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of audiology[130, 131, 132, 133, 134] revealed that they, too, know of no research which had been done on time perception by hearing impaired subjects. Articles, which several of them thought might be pertinent, were not related to perception of duration but, rather, dealt with threshold values and differential sensitivity.

SUMMARY

There are several main categories of the theories of time perception. One of these holds that within the central nervous system, memory traces or brain traces are established which are later used for comparison between two stimuli.

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[130]Letter from Ira J. Hirsh, Director of Research, Central Institute for the Deaf, St. Louis, Missouri, March 1, 1966.

[131]Letter from T. Dean Clack, Kresge Hearing Research Institute, University of Michigan Medical School, Ann Arbor, Michigan, March 7, 1966.

[132]Letter from James Jerger, Director of Research, Houston Speech and Hearing Center Research Institute, Houston, Texas, March 2, 1966.

[133]Letter from Merle Lawrence, Director of Kresge Hearing Research Institute, University of Michigan Medical School, Ann Arbor, Michigan, March 3, 1966.

[134]Letter from Howard B. Ruhm, Director of Audiological Research, The University of Oklahoma Medical Center, Oklahoma City, Oklahoma, March 10, 1966.

Another theory states that within the body and physiological mechanisms there are cue devices used in time perception. A number of researchers believe that time is perceived by the amount of change that takes place. Relative to this is the concern that there is a limit to the amount of experience that is considered within one unit-of-organization.

Primitive people perceive time by observation of the natural phenomena and by noting bodily changes.

Time perception by children is generally on the adult level by the age of 14 years. The development of language plays an important part in this developmental process.

In the consideration of Psychophysical problems in the research on time perception, one will encounter Weber's Law, time-order error, indifference interval, and methods used in judging. Most research on time perception has employed the psychophysical methods of comparison and reproduction, although the methods of estimation and production have been used extensively.

Sex differences, age differences, motivation and attitude, and practice effects, most researchers agree, are important factors in the perception of time.

A survey of literature reveals that there has been no research, *per se*, done on the perception of time by persons with hearing impairments.

CHAPTER III

SUBJECTS, INSTRUMENTATION, AND PROCEDURES

In the present study the psychometric method of reproduction of the stimulus was employed. Guilford[135] maintains that since this allows the judgments to be made by some action on the part of the subject it is the "most natural" psychophysical method. Furthermore, he maintains that a favorable attitude is created in the subject by his being able to control the stimulus. The subjects in this study were to attempt to reproduce the durations of 27 different stimuli made up of combinations of the parameters of duration, frequency, and loudness.

SUBJECTS

Five subjects were selected for this experiment from the clientele of the Speech and Hearing Clinic at Michigan State University. All five of the subjects had binaural sensori-neural hearing impairments, ascertained by pure tone air-conduction and bone-conduction audiometry, with an

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[135] J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book Company, Inc., 1954), p. 97.

average loss of 27 to 33 decibels through the speech range frequencies of 500, 1000, and 2000 cps. The subjects had thresholds in both ears within 5 decibels of each other. The subjects were adults of ages 18, 23, 26, 37 and 43 years with a mean age of 29.4 years. Subjects had been aware of their hearing deficits for at least 10 years. There were two males and three females. The initial contact with each subject was made by telephone. The text of the experimenters' telephone solicitation for subject participation is given in Appendix C.

INSTRUMENTATION

Apparatus. The following instruments were used for recording and presentation of the stimuli to the subjects:

1. Low frequency oscillator (Hewlitt-Packard, Model 202-C)
2. Timer (Hunter, Model 100-C, Series D)
3. Tape recorder (Ampex, Model 601-2)
4. Mixer (Ampex, Model MX-35)
5. Line amplifiers (Ampex, Model 620)
6. Magnetic recording tape (3M, Type 203)
7. Electronic voltmeter (Bruel and Kjaer, Type 2409)
8. Sound level meter (Bruel and Kjaer, Type 2203)
9. Earphones (Telephonics, Model TDH-39)
10. Aircraft timer stop-computor (Hughes, Model J 9101)
11. 24 volt power supply (Dressen-Barnes, Model 28 2MX)

Recording the Stimulus. The stimulus tones for both practice and experimental sessions were generated by the low-frequency oscillator and placed on magnetic recording tape. The signal was timed to within three one-hundredths of the duration desired and sent into line one of the tape recorder. It then passed on to the mixer. At this point the signal was amplified further by the mixer and the line amplifier. Each signal was monitored on the voltmeter. When the programmed stimulus had ended the tone was switched from line one to line two of the recorder. This tone was sent through line two of the mixer, amplified, and also monitored on the voltmeter. The entire recording system had previously been calibrated through the earphones to be used by the subjects during the experimental sessions. Therefore, the reading on the voltmeter represented the level to be heard by the subjects through the earphones. Figure 1 shows a diagram of the recording instrumentation.

<u>Selection of Stimuli</u>. Three frequencies were chosen for presentation to the subjects: 500, 1000, and 2000 cycles per second. These frequencies represent the frequency ranges that are critically important for understanding human speech.[136] They also represent octave steps on

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[136]Hallowell Davis and S. Richard Silverman (eds.), <u>Hearing and Deafness</u> (New York: Holt, Rinehart and Winston, Inc., 1960), p. 97.

the musical frequency scale.

PROCEDURES

The stimuli were presented at three loudness levels: 60, 70, and 80 phons. Phons are loudness units based on the psychological interpretation of intensity ascertained by having subjects equate the loudness of other frequencies to the loudness of a 1000 cycle tone. Fletcher and Munson[137] established equal loudness contours, using this loudness matching procedure. The various contours were established with the 1000 cycle reference tone set in 10 decibel steps.

It was necessary to determine the intensity equivalents in decibels (re. .0002 dyne per square centimeter) at which to present the stimuli to the subjects. The researcher employed the intensity levels used by Deal.[138] They are presented in Table I.

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[137]Harvey Fletcher and W. A. Munson, "Loudness, Its finition, Measurement, and Calculation," Journal Acousti-l Society of America, V (October, 1933), p. 97.

[138]Deal, op. cit., p. 106.

TABLE I

THE AVERAGED INTERPOLATIONS FOR THE INTENSITY EQUIVALENTS OF PHONS GIVEN IN DECIBELS RE 0.0002 DYNE/CM^2

FREQUENCIES	PHONS 60	PHONS 70	PHONS 80
500	61	70	80
1000	60	70	80
2000	60	70	79

Sounds were presented at three durations: 1, 5, and 9 seconds. Because it was important that the results of this experiment measure the subject's reproduction of the duration rather than his reaction time, the minimum duration was set at 1.0 second.

Attempting to keep the presentation duration as a "unity of duration," that is, a single event, the maximum duration was set at 9.0 seconds. Woodrow[139] ascertained that the upper limit of unity fell somewhere between 2.3 and 12.0 seconds.

The stimulus tones were also presented for the 5 second duration, which is the mid point between 1 and 9 seconds.

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[139]Woodrow, "Time Perception," p. 1230.

With three frequencies, three loudness levels, and three durations, a total of twenty-seven combinations of stimuli was possible. For example, one combination was: 1 second, 500 cycles per second, 60 phons. Ten different randomizations (without replacement) were made of these twenty-seven combinations. Each subject heard all ten of the randomizations. Stimuli for presentation during the practice session, prior to the experimental session, were randomized in the same manner using the same table of random numbers.[140] Figure 1 shows a diagram of the instrumentation employed.

Manner of Presentation. Each subject was contacted by telephone for an evening appointment hour for the experimental session. When he arrived, he was seated and acquainted with the part of the apparatus with which he would be concerned. Next, he read the printed instructions on how to respond to the stimuli and was allowed to ask questions about his task and they were answered by the experienter. The earphones were adjusted to the subject's ears, nd the subject was given a practice session using twenty timuli. Again, the experimenter answered any questions

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[140]Hubert M. Blalock, Jr., Social Statistics (New ork: McGraw-Hill Book Company, 1960), pp. 437-440.

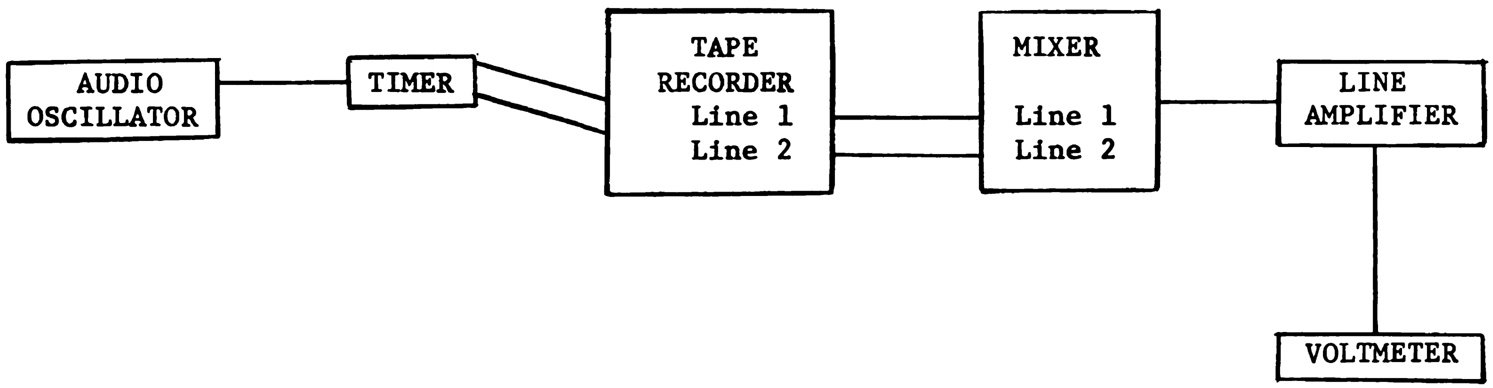

FIG. I Block Diagram of Recording Apparatus.

asked by the subject.

Following the explanation of the procedure and the practice session, the experimental session was begun. The stimulus was presented to the subject; the subject was given 15 seconds in which to make his reproduction of the stimulus duration. The 15 second interstimulus interval was held constant, regardless of the duration of the stimulus.

Subject Response. After the subject had heard the stimulus, he was to depress a telegraph key for as long as he thought the stimulus had lasted. When the telegraph key was depressed, the subject heard a sound of the same frequency and the same loudness heard during the stimulus presentation, to aid the subject in the reproduction of the stimulus duration.

The following are the instructions read by the subject prior to the practice session:

> The task before you is the reproduction of various time intervals. You will hear a series of tones of varied durations, frequencies, and loudness levels. The sound you will hear for each stimulus will be continuous. As soon as the tone ceases, you are to depress the telegraph key which you have before you and hold it down for as long as you think the sound lasted. When the key is depressed you will hear the same pitch and the same loudness that you heard during the stimulus.
>
> This is not a test of your reaction time;

therefore, it is not important that you depress the key with great speed. If you should depress the key too soon you will cut off the stimulus, thus not hearing all of it. On the other hand, as soon as you are positive the stimulus sound has ceased, you are to depress the key. There will be adequate time for you to make your reproduction of the stimulus duration; but the longer you wait, the more likely you are to make errors. You do not have unlimited time to make your reproductions; therefore, if you wait too long before responding you will be cutting off the next stimulus sound. Care should be taken not to depress the key accidentally. The intervals between stimuli will all be the same. At times you will have a short period of time to wait after making your response; at other times you will have a longer period to wait. There will be no alerting signal or tone to indicate when the next stimulus will occur. The onset of the stimulus will be your alerting signal. Try to stay ready throughout the entire test for the onset of the stimulus.

You are to be concerned only with the experience of the duration of the sound. It is important that you make no overt or covert attempts to count out the time interval you are reproducing, neither during the stimulus nor during your reproduction of it. Do not count to yourself, look at your watch, make rhythmic motions, be conscious of your respiration, or use any other conscious measuring device. Because this is a test of your ability to reproduce temporal intervals, not of your ability to count off segments of time, pay attention only to the sensation of the duration.

During the practice you will be given twenty stimuli. If you have any questions regarding your test, please ask them during or after the practice session. You are to ask no questions during the presentation of the 270 stimuli in the test.

The stimuli were presented in ten randomized schedules of twenty-seven sounds each. These ten were presented in random order. The subject was given a thirty minute rest break between the presentations of the fifth and sixth schedules. Because, as the experimentation resumed with schedule six, one subject failed to release the telegraph key until after the second and third stimuli were begun, the experimenter gave her another practice session then proceeded with the experiment.

The results of measurements with a sound pressure level meter showed that the ambient room noise at the subject's ear level outside the ear cushions was a mean 52.3 dB (re. 0.0002 dyne per square centimeter). Sound pressure readings were taken every ten seconds for three minutes and the mean was calculated.

Response to the Stimuli. The taped stimuli were played through channel one of the tape recorder into the mixer and on to the earphones when the subject depressed the telegraph key, channel two of the tape recorder into the mixer permitting the subject to again hear the tone, as it was presented through outputs A and B. The depressing of the key also started the timer used to time the duration of the responses. Figure 2 shows a block diagram of the instrumentation for the response.

Recording the Response Durations. The timer dial

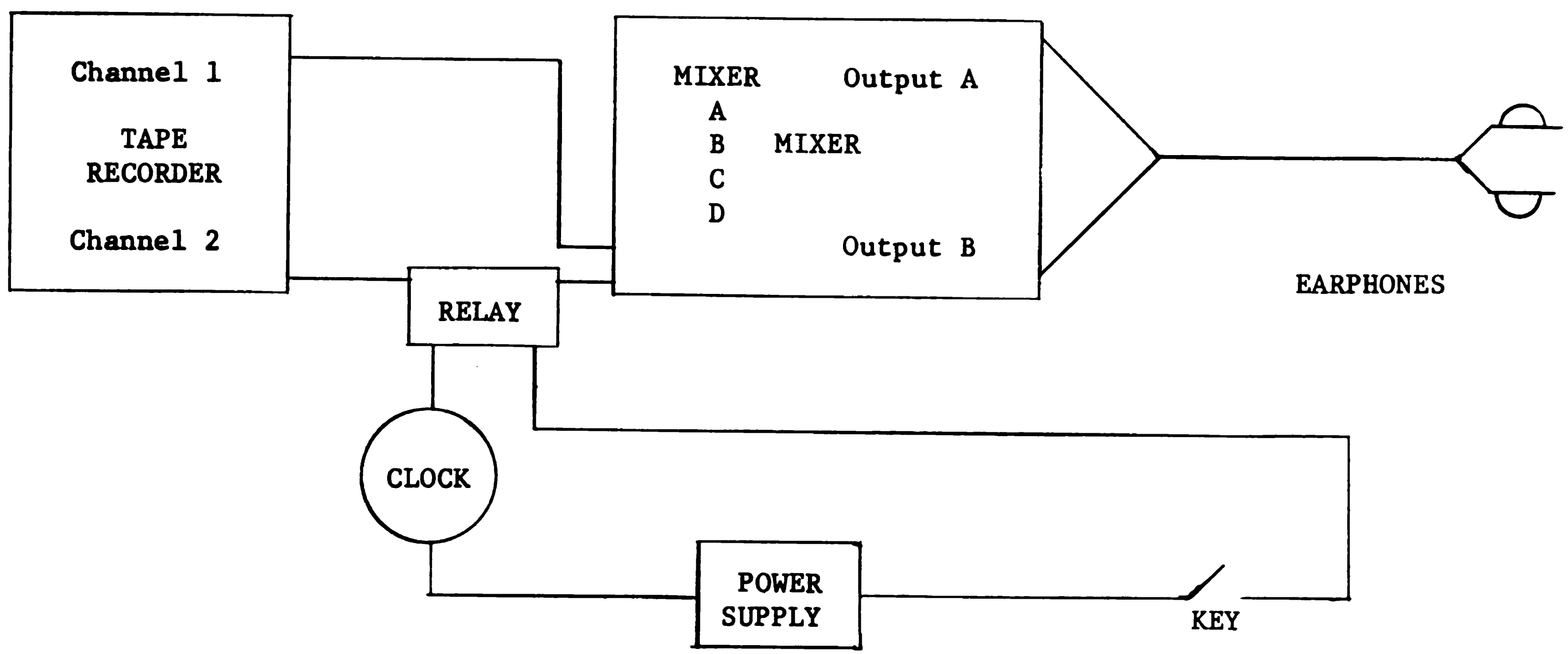

FIG. 2 Block Diagram of Instrumentation for the Experimental Sessions.

was read by the experimenter and an assistant. The reading was recorded by the assistant while the experimenter reset the timer.

CHAPTER IV

RESULTS AND DISCUSSION

In accordance with the research design presented in Chapter III, each subject reproduced the 27 combinations of duration, frequency, and loudness. The stimuli were presented in 10 randomized schedules thus resulting in 10 responses to each stimulus combination, or a total of 270 responses by each subject.

These responses constituted the raw data of the study. The statistical procedure employed in the analyses of the raw data was as follows: The difference between the actual duration of the stimulus and the duration of the subject's response to that duration was calculated as the difference-time (ΔT). Next, this difference-time was divided by the actual duration of the stimulus. This established a ratio, $\frac{\Delta T}{T}$. During these calculations the sign of the reproduction was retained, i.e., the ratio carried a minus sign if the reproduction was shorter than the stimulus duration, or underestimated, and a plus sign if the reproduction was longer than the stimulus duration, or overestimated. Employing a ratio permits a difference-time of .10 second to be of greater magnitude when it was in the judgment of a shorter stimulus, such as a 1-second stimulus, than it would for a longer stimulus, in this case the 9-second stimulus.

With each subject having reproduced each combination of duration, frequency, and loudness 10 times, the mean of those 10 reproductions was considered as that subject's response to that combination. Therefore, with each subject giving a total of 270 responses, he had a total of 27 averaged reproductions. (See Appendix B for the means of the raw data.)

The Analysis of Variance. The data were treated by an analysis of variance. When the analysis of variance is employed, one of the assumptions made is that there is homoscedasticity. To ascertain whether or not such an assumption can be made with these data, an F-Max test was computed for duration, frequency, and loudness.[141] Table 2 contains the results.

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[141]Blalock, _op. cit._, p. 249.

TABLE 2

VARIANCES USED TO COMPUTE THE F-MAX TESTS FOR HOMOSCEDASTICITY FOR DURATION, FREQUENCY, AND LOUDNESS

DURATION	VARIANCE	FREQUENCY	VARIANCE	LOUDNESS	VARIANCE
1 sec.	.086	500 cps	.019	60 phons	.028
5 sec.	.004	1000 cps	.027	70 phons	.020
9 sec.	.013	2000 cps	.020	80 phons	.018
F-Max = 21.5*		F-Max = 1.35*		F-Max = 1.56*	

N = 27
*2.13 significant at the 1% level of confidence.[142]

The results of the F-Max test showed lack of homogeneity of variance for duration, whereas the variables of frequency and loudness showed homogeneity of variance. With these results in mind, the assumption of homoscedasticity can be made only in part. As Ferguson states, "Tests of normality and homogeneity of variance may be applied; but these tests are not very sensitive for small samples."[143,144] Ferguson states further, "When the samples are fairly small, it is usually not possible to rigorously demonstrate lack

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[142] Ibid., p. 454.

[143] George A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, Inc., 1959), p. 138.

[144] It seems to be that many researchers consider any sample less than 30 as a small sample.

of normality in the data."[145]

After the testing for homoscedasticity the data were subjected to a 3 x 3 x 3 factorial design analysis of variance with the assistance of the CDC 3600 computer.[146] An analysis of variance routine (FACREP, option 3) was employed. Table 3 presents the results of this analysis.

TABLE 3

SUMMARY TABLE FOR THE FACTORIAL DESIGN ANALYSIS OF VARIANCE*

SOURCE OF VARIANCE	SUM OF SQUARES	DF	MEAN SQUARE	F	SIG. AT 1% LEVEL[147]
DURATION (D)	7.3072	2	3.6536	222.7805	4.61
FREQUENCY (F)	.0042	2	.0021	.1280	4.61
D X F	.2069	4	.0517	3.1524	3.32
LOUDNESS (L)	.0418	2	.0209	1.2744	4.61
D X L	.0480	4	.0120	.7317	3.32
F X L	.0547	4	.0137	.8354	3.32
D X F X L	.2049	8	.0256	1.5610	2.51
ERROR	21.6850	1323	.0164		
TOTAL	29.5527	1349	.		

*Individual differences were accounted for in the error term.

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[145]Ferguson, op. cit., p. 240.

[146]D. F. Kiel, A. L. Kenworthy, and W. L. Ruble, Analysis of Variance Routines (East Lansing, Michigan: Michigan State University, September 30, 1963), p. 24.

[147]Ferguson, op. cit., pp. 310-313.

The only significant variable in this analysis was that of duration. There were no significant differences in the subjects' reproductions among the different loudness levels, nor among the different frequencies. The results showed no significant interactions between duration and loudness, frequency and loudness, duration and frequency, or interaction among duration, frequency, and loudness.

On the basis of this anlysis, one null hypothesis was rejected:

1. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 1 second, 5 seconds, and 9 seconds.

On the basis of the same analysis the following null hypotheses were not rejected:

2. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 500 cps, 1000 cps, and 2000 cps.

3. There is no significant variation in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals of 60 phons, 70 phons, and 80 phons.

4. There is no significant interaction between duration and frequency in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

5. There is no significant interaction between duration and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

6. There is no significant interaction between frequency and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

7. There is no significant interaction among duration, frequency, and loudness in the performance of persons with sensori-neural hearing impairments in reproducing temporal intervals.

Table 4 shows the means and standard deviations of the reproductions of each stimulus duration in terms of difference-time. The variables of requency and loudness were not included because of their having no significant effect.

TABLE 4

MEANS AND STANDARD DEVIATIONS OF THE REPRODUCTIONS OF EACH STIMULUS DURATION IN TERMS OF DIFFERENCE-TIME

	MEAN	STANDARD DEVIATION
One Second	.08290	.16932
Five Seconds	-.05483	.09179
Nine Seconds	-.08660	.11157

On Figure 3, $\frac{\Delta T}{T}$ is plotted as a function of duration showing the means and standard deviations of reproduced temporal intervals. A critical difference test was used to determine where the difference lay among the different

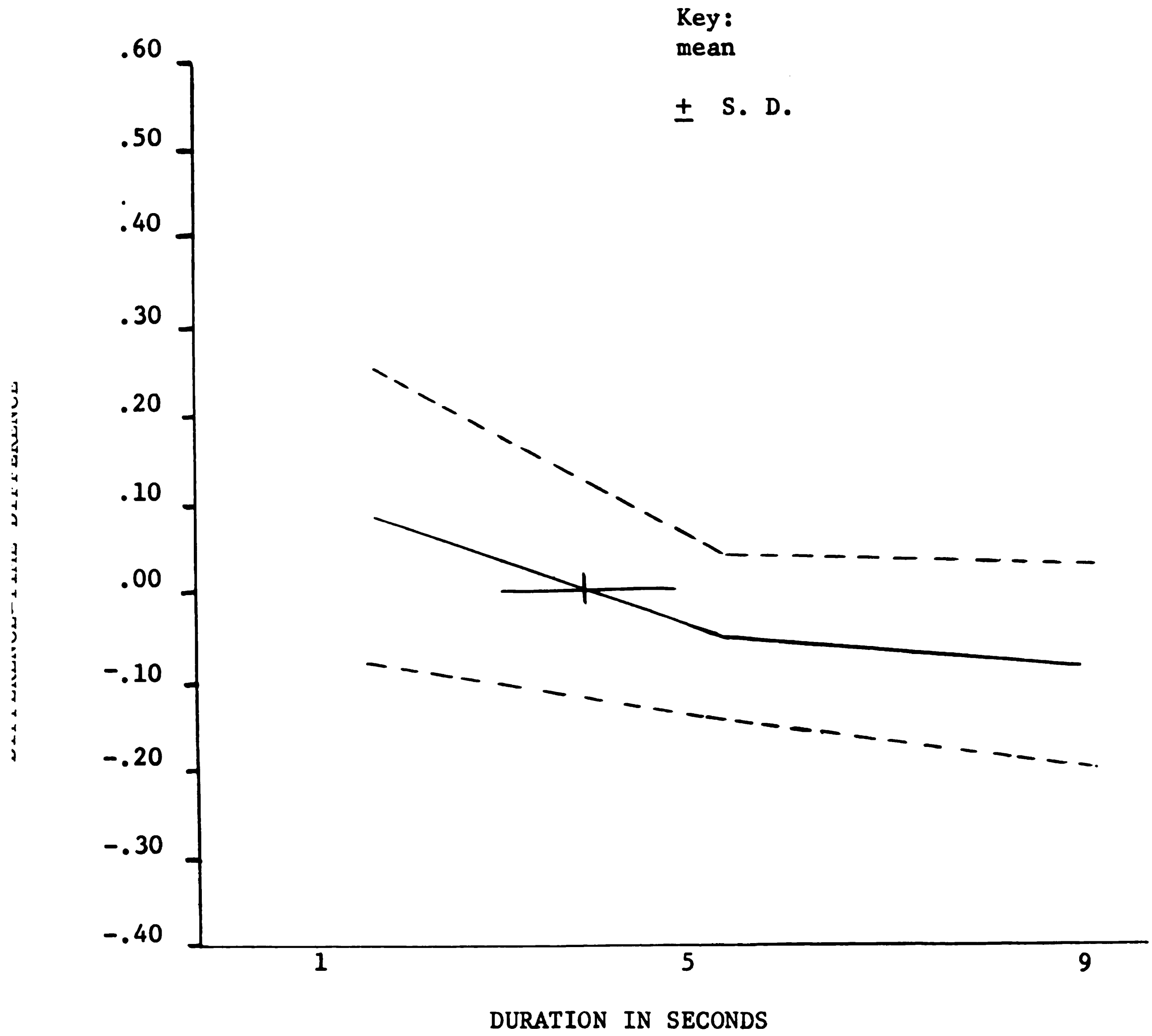

FIG. 3 ΔT Plotted as a Function of Duration Showing Means and Standard Deviations of Reproduced Temporal Intervals.

durations.[148] A difference of more than 0.02591 between means would be significant at the 1% level.

The results of the critical difference test are found in Table 5. According to this test there are significant differences between all three of the possible pairs of duration: 1-second and 5-seconds, 1-second and 9-seconds, and 5-seconds and 9-seconds.

TABLE 5

CRITICAL DIFFERENCES BETWEEN THE MEANS OF REPRODUCTION TIMES

MEANS	DIFFERENCES	
	5 seconds	9 seconds
1 second = .08291	.13774*	.16951*
5 seconds = -.05483		.03177
9 seconds = -.08660		

*Differences between two means significant at the 1% level.

[148] K. A. Brownlee, Statistical Theory and Methodology in Science and Engineering (New York: John Wiley and Sons, Inc., 1960), p. 252.

DISCUSSION

Weber's Law. Through experimentation some researchers[149,150] have come to the conclusion that Weber's Law does not apply consistently to time. Should it be true that Weber's Law does not hold for judgments of time, the curves presented in Figure 3 would be constant or flat, rather than abruptly changed at the middle frequency. The results of this study seem to indicate that Weber's Law may come closer to being true for longer durations than those used in this study.

These findings seem to agree, in part, with the results obtained by Gilliland,[151] who noted that Weber's Law seemed to hold for durations of 4-27 seconds, and Henry,[152] who indicated that such a ratio decreased as the duration increased. The curve for this study is much more flat than the one obtained by Deal[153] working with normal hearing

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[149]Gilliland, op. cit., p. 255.

[150]Franklin M. Henry, "Discrimination of the Duration of a Sound," Journal of Experimental Psychology, XXXVIII, No. 6 (December, 1948), pp. 737-739.

[151]Gilliland, loc. cit.

[152]Henry, loc. cit.

[153]Deal, op. cit., pp. 109, 110.

subjects. In the event of failure of the subject to reproduce the duration at all, the maximum possible underestimation ratio is 1.0. On the other hand, there is no limit to the possibility of the ratio for an overestimation.

Effects of Frequency and Loudness. A review of the literature reveals that not all researchers have obtained the same results. According to research reported by Fraisse,[154] a brief duration filled with sound will seem longer if it is more intense. He added, however, that for longer durations the effects of intensity upon the apparent duration decrease. With a stimulus that varied during its presentation, Wallace and Rabin[155] observed that the duration tends to be overestimated if the intensity is increased during the presentation.

The results of the present study agree with those results obtained by Deal.[156] There is no significant effect by loudness on the perception of duration within the limits used in this study. There were no significant effects by other parameters interacting with the duration

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[154] Fraisse, op. cit., pp. 130-134.

[155] Melvin Wallace and Albert I. Rabin, "Temporal Experience," Psychological Bulletin, LVII (May, 1960), p. 220.

[156] Deal, op. cit., p. 115.

variable. As noted by Deal,[157] should these parameters be extended, they may indicate different effects.

Serial Position. With the stimulus sequences being presented in 10 random orders it was believed that no effect of serial position should be considered. To add to the safeguard against effect of serial position each of the subjects was presented the 10 randomizations in different orders. The order of which set of 10 randomizations was to be given to each subject was obtained from a table of random numbers.

Sex Differences. It was noted in Chapter II that men generally overestimated slightly a stimulus duration, whereas women greatly overestimated it and were less accurate.[158] The results of the present study show that the two men overestimated the 1-second duration more than did the three women; the men underestimated the 5-second duration slightly more than did the women; but the women underestimated the 9-second duration almost twice the amount the men did. Data for this are found in Table 6. Examination of the raw data reveals that, in general, the women

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[157]Deal, op. cit., p. 115.

[158]Fraisse, op. cit., p. 145.

overestimated the stimuli more and were less consistent than the men.

TABLE 6

MEANS OF SUBJECTS RESPONSES
TO STIMULI DURATIONS

	SUBJECT				
	I	II*	III*	IV	V
Duration I	.120	.040	.914	.039	.021
Duration II	-.083	-.057	-.121	-.060	-.054
Duration III	-.184	-.059	-.052	-.109	-.030

*Subjects II and III are males

<u>Subject Differences</u>. The subjects were asked, as detailed in Chapter III, to use no conscious method of counting or calculating the length of the stimulus duration or the response duration. It was believed that this would help lessen the possibility of subject differences by preventing the use of some measuring device a subject may have practiced in the performance of some similar task. All subjects believed, at the end of the experimental session, that they had complied with the request. Several comments were made, such as, "I kept wondering, 'How long would someone harder of hearing than I estimate the sound to be?'"

Regardless of the subjects' comments, their responses were consistent with those found by Woodrow: responses tend to be short when subjects reproduce intervals in an automatic manner.[159]

All subjects overestimated the 1-second duration from .120 to .020 second, underestimated the 5-second duration from -.021 to -.083 second, and underestimated the 9-second duration from -.030 to -.184 second.

Effects of Duration and Frequency. The finding in this study, that there is no significant effect by interaction between duration and frequency, differs from the finding by Triplett[160] that a high pitched sound seems longer than does one of low pitch. Cohen, Hansel, and Sylvester,[161] found, conversely, that there was a greater inclination for subjects to report higher tones as being shorter. In a study which is somewhat related, Fraisse[162] found that when sounds setting off an empty interval are of higher pitch, the interval will appear longer than when limited by sounds

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[159]Woodrow, "Individual Differences in the Reproduction of Temporal Intervals," pp. 271-281.

[160]Triplett, op. cit., pp. 201-281.

[161]Cohen, loc. cit.

[162]Fraisse, op. cit., p. 130.

of lower pitch. Furthermore, he noted that as the difference in pitch of the limiting sounds increases, the longer the interval seems to be.

Effects of Duration and Loudness. Within the limits of this study there is no significant effect by interaction between duration and frequency.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The study of time and the perception of it has occupied the attention of scientists for many years. Both objective and subjective researches have been done on the perception of time by persons with normal hearing, with somewhat contradictory findings. Most researchers do agree, however, that the perception of time is an individual phenomenon influenced by numerous factors.

The purpose of this study was to investigate the effects of the three parameters - duration, frequency, and loudness - upon the ability of sensori-neural hearing impaired subjects to reproduce temporal intervals.

Even though there has been much study of the effects of the auditory stimulus interval upon the perception of duration, few studies have been concerned with the effects of the interaction of duration, frequency, and loudness. In spite of lack of agreement by all researchers, there seems to be a general agreement that a high pitched sound is perceived longer than a low pitched sound, and that long sound stimuli are less accurately perceived than are shorter sound stimuli. There is apparently no literature on the effects of these parameters on the ability of sensori-neural hearing impaired persons to perceive stimuli durations.

Stimuli frequencies of 500, 1000, and 2000 cycles per second were presented at 60, 70, and 80 phon levels for 1, 5, and 9 seconds. Twenty-seven different combinations of these parameters recorded on magnetic recording tape were presented to five experimental subjects. Ten different randomized schedules of these combinations were presented to each subject after a 20-stimulus practice session.

After the subject heard each stimulus, he depressed a telegraph key for the same length of time he had believed the stimulus to have lasted. During the time the subject depressed the key, he heard a sound of the same frequency and loudness as the stimulus sound he had just heard. This procedure was repeated, within the random schedules, 10 times for each of the 27 stimulus combinations.

The ratio, $\frac{\Delta T}{T}$, was computed by taking the difference-time (the difference between the stimulus duration and the response duration) and dividing it by the actual duration of the stimulus. The ratio carried a minus sign if

the reproduction was shorter than the stimulus duration, and it carried a plus sign if the reproduction was longer. The mean of the subject's 10 reproductions for each of the 27 combinations was considered the subject's score.

The F-Max test computation revealed that there was a lack of homogeneity for some of the research parameters. As noted in Chapter IV, however, Ferguson maintains that for a small sample, a lack of homogeneity has a very limited effect upon an analysis of variance.[163] The results of the analysis of variance revealed that there was a markedly significant effect by the duration variable. The effects of the variables of frequency and loudness were minimal or nonexistent as was the interaction among duration, frequency, and loudness. Furthermore, there was no significant interaction among the three parameters. From a critical difference test it was found that significant differences were present for all frequencies as follows: between durations of 1 and 5 seconds, 1 and 9 seconds, and 5 and 9 seconds.

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[163]Ferguson, op. cit., pp. 138, 240.

CONCLUSIONS

The following conclusions seem to be warranted within the limits of this study:

1. The reproduction of pure-tone filled temporal intervals by sensori-neural hearing impaired subjects <u>is</u> affected by the duration of the stimulus. Significant differences in time perception exist between the pairs of pure-tone stimuli of one and five seconds, one and nine seconds, and five and nine seconds. The five second duration is most accurately reproduced, whereas the one second duration is the most erroneously reproduced.

2. The reproduction of pure-tone filled temporal intervals by sensori-neural hearing impaired subjects <u>is not</u> affected by the loudness of the stimulus presentation. A sound that is slightly above the pure-tone threshold such as 5dB above, is as accurately reproduced as is a sound that is presented well above the threshold, such as 25dB above.

3. The reproduction of pure-tone filled temporal intervals by sensori-neural hearing impaired subjects <u>is not</u> affected by the frequency of the stimulus presentation.

4. The interaction among duration, frequency, and loudness has no affect upon the reproduction of temporal intervals by sensori-neural hearing impaired subjects.

IMPLICATIONS FOR FURTHER RESEARCH

Studies of time perception as experienced by persons with sensori-neural or conductive hearing impairments may well include the following:

1. Extension of Parameters. Extend the parameters employed in this study to include longer and shorter sounds, higher and lower sounds, and louder and softer sounds to determine whether the results obtained in this study will hold for these added stimuli.

2. Changing the Content of the Interval. Select stimuli other than pure tones against a background of silence. Some of the following might be used to fill the duration: narrow-band sound with selected mid-frequencies, filtered speech, competing speech sounds, speech by males and/or females, and speech with background sounds such as street noise or music. The researcher could use empty intervals bounded by any of the sounds noted above. Intermittent presentation or pulsed presentations could be employed while asking the subject to estimate the lapse time or the

net time of some part of the duration.

3. The Use of Different Psychophysical Methods. Employ some other psychophysical method of research such as the method of fractionation or the method of paired comparisons for ascertaining the effects of the same parameters used in this study.

4. Individual Differences. Replicate this study on subjects who have sustained their hearing impairments for various lengths of time. Select subjects with unilateral hearing impairments to ascertain the possible presence of perceptual differences between the two ears. Note the perception of time by persons with multiple handicaps as contrasted with persons with the same handicaps except with normal hearing.

5. Time Perception in Speech and Hearing Disorders. Perception of duration may be affected by both neurological and psychological disturbance. Typical of the neurologically disturbed is the brain damaged or aphasic, who may suffer both sensori-motor and symbolic difficulties. The establishing of the existence of a difference in time perception by these persons may alter the testing and rehabilitation techniques employed with them.

Functional speech disorders such as stuttering may be caused, in part, by distorted time perception. This might be particularly true in cases where the stuttering involves an approach-avoidance conflict. The entire system of interacting time and rhythm may be malfunctioning. There is a possibility that some articulation disorders originate by virtue of distorted vowel perception.

Along with this is the fact that delayed speech is frequently caused by improper auditory perception, which in turn may be due to improper time perception.

Research on the perception of time as experienced by hearing impaired has just begun. Routine pure tone testing reveals that this population has an altered perception of frequency and intensity and their psychological correlates of pitch and loudness respectively. Detailed knowledge of the perception of duration by this population is not yet in hand.

An extensive survey of literature reveals that no studies of time perception have been done on either conductive or sensori-neural hearing handicapped subjects. A follow-up study of this one should be done on persons with conductive hearing impairments. This present study could be replicated with subjects sustaining different degrees of hearing impairment. A study could be done on normal hearing subjects and repeated on the same subjects as they sustain experimental hearing losses.

The establishing of any difference in time perception by the acoustically handicapped may indicate the need for a change in aural habilitation or rehabilitation procedures. It may be found that the sound stimulus for testing or rehabilitation should be sustained for a different length of time than is now believed optimal.

As speech reading is considered, it may be found that the rate of movement of the articulatory mechanism should be altered to facilitate the learning of speech reading by those who demonstrate a different perception of time. Research could be designed to ascertain the affects of the teaching of speech reading at different rates.

In an effort to create a test or series of tests for the perception of time by a hearing handicapped population, as it would be used in routine speech and hearing therapy, there must be concern over the psychophysical method and the specific stimulus to be employed. A key consideration must be for ease of administration of the test and simplicity of interpretation of results.

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APPENDIX A

SUBJECT I

DIFFERENCE BETWEEN ACTUAL STIMULUS DURATION AND SUBJECT RESPONSE

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	.03	.09	- .08	.19	.11	.07	.01	- .15	.19	- .11
2	- .36	-1.12	-1.00	-1.31	.06	- .21	-1.14	- .22	- .15	- .40
3	-1.56	-2.72	-2.52	-2.02	-1.64	-1.29	-1.14	-1.23	1.56	-1.08
4	.02	.02	- .12	- .02	- .06	- .03	- .18	.02	.35	- .19
5	.03	- .90	- .63	- .64	- .68	- .33	- .60	- .53	- .47	- .26
6	-1.82	-2.45	-1.60	-1.63	-.196	-2.33	-1.73	.50	.39	- .32
7	.01	.18	.32	- .11	.15	.00	- .01	.12	- .16	.16
8	- .97	- .84	-1.13	-1.59	- .38	-1.14	- .44	.11	.81	- .18
9	-2.41	-2.77	-2.02	-2.10	-1.60	-1.75	-2.42	-1.21	-1.23	-2.73
10	.99	.71	.85	.36	- .25	.52	.85	.40	.47	.41
11	- .35	- .22	- .11	- .90	- .20	- .15	- .60	.23	- .02	.02
12	-1.88	-1.58	-1.61	-5.03	-2.10	- .30	-1.24	-1.89	-1.77	-1.38
13	.02	.13	.32	- .18	- .21	.05	.06	.23	.04	.18
14	-1.08	-1.58	- .72	- .36	- .24	-1.25	- .05	.97	.31	- .73
15	- .68	-2.69	-2.26	-1.13	- .53	-2.25	-2.91	- .17	- .15	.18
16	.21	.27	.18	.09	- .05	- .06	- .05	.10	.11	.16
17	- .45	- .39	- .15	.04	- .70	- .89	- .65	.57	- .78	- .47
18	- .23	-3.94	-2.11	-3.77	- .13	.05	-1.19	- .79	-1.78	-1.49
19	.21	.16	.12	.06	.10	.17	- .07	- .09	- .10	- .21
20	- .54	- .53	- .11	.53	-1.00	- .17	.17	.19	- .21	- .11
21	-1.79	- .18	-1.49	-1.08	-1.64	-1.52	-1.74	- .18	-1.29	- .58
22	.22	.20	.14	.16	.09	.22	.15	.22	.17	.03
23	- .64	- .98	- .44	- .45	- .54	.52	- .08	.42	- .16	- .04
24	-1.11	-2.37	-2.05	-2.10	-1.59	-2.66	-3.40	-2.16	-1.91	-1.80
25	.02	.25	.01	.25	.07	.00	- .07	.21	.09	.22
26	- .65	- .33	- .58	.66	- .69	.35	-1.00	- .34	- .07	-1.13
27	-2.70	-1.97	-3.64	-1.94	-2.99	-1.78	-1.71	-5.96	- .55	-2.19

SUBJECT II

DIFFERENCE BETWEEN ACTUAL STIMULUS DURATION AND SUBJECT RESPONSE

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	- .04	.36	- .19	.38	- .18	- .02	- .11	.11	- .11	- .01
2	- .15	- .62	- .53	- .26	- .31	- .89	- .92	- .55	- .40	- .43
3	.03	- .37	- .45	-1.21	- .86	-1.43	-1.65	- .18	- .11	-1.01
4	.16	.24	- .15	.28	- .19	- .21	.06	.05	.07	.12
5	- .59	.35	- .43	- .27	- .68	- .48	- .52	- .48	- .12	- .63
6	- .38	- .86	-1.57	-1.02	.11	- .64	-1.17	.05	- .99	- .03
7	.00	.20	.18	- .11	.10	- .22	- .10	.20	.16	- .06
8	- .30	- .28	- .41	.29	- .42	.00	- .23	- .32	- .48	- .32
9	-1.76	- .64	- .47	-1.23	- .62	- .18	- .56	- .90	- .72	.07
10	.21	.18	.03	.09	- .21	.05	.15	- .14	- .04	- .22
11	.59	- .03	- .37	- .13	- .28	- .53	- .76	- .43	- .49	- .41
12	- .45	- .38	- .49	- .57	- .14	- .33	-8.11	- .78	-1.54	- .41
13	- .22	.18	- .09	- .10	- .26	.15	.06	- .19	- .19	- .06
14	-1.62	.31	- .58	- .48	- .22	- .01	.05	- .64	- .24	- .38
15	- .65	-1.01	- .81	- .14	- .90	- .92	- .60	- .84	-1.00	- .03
16	.22	.27	.08	.11	- .12	.04	- .01	.15	.08	.19
17	.01	- .06	- .61	- .22	- .46	- .83	- .40	- .18	- .16	- .52
18	-1.26	- .79	.24	-1.30	- .67	- .76	- .91	- .69	.17	- .66
19	.13	.20	- .02	.00	- .12	.00	- .01	.03	.19	- .14
20	.77	- .07	- .04	.08	- .29	- .28	- .05	- .54	.07	- .27
21	- .08	- .79	-1.01	- .82	.29	- .19	- .62	- .86	- .84	- .78
22	.18	.17	.02	.24	- .06	.18	- .03	- .04	- .02	- .04
23	- .18	- .30	- .31	.68	- .42	- .40	- .92	.19	- .43	- .52
24	- .11	- .80	- .43	- .57	- .38	- .21	- .61	- .42	- .08	- .71
25	.04	.27	.01	.11	- .11	- .05	.06	- .01	.11	.03
26	- .30	- .03	.31	- .09	- .26	- .46	- .39	- .37	- .29	- .89
27	- .43	- .12	.14	- .58	- .27	- .35	.45	- .48	- .50	- .33

SUBJECT III

DIFFERENCE BETWEEN ACTUAL STIMULUS DURATION AND SUBJECT RESPONSE

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	.14	.31	.05	.28	.04	.23	.28	.09	.25	.18
2	.04	.00	.29	.00	- .14	.15	- .08	.04	- .19	- .02
3	- .89	- .56	.09	.00	-1.74	- .36	- .13	.58	- .79	- .49
4	.39	.24	.25	.79	.22	.12	.35	.14	.28	.21
5	- .50	.69	.94	- .24	-1.16	.21	.01	.50	- .57	- .09
6	.06	- .64	- .49	-1.12	- .27	- .27	- .53	-1.15	-1.31	.17
7	.21	.34	.31	.30	.09	.04	.08	.12	.13	.12
8	- .06	- .19	.20	-1.04	-1.14	.18	.59	.29	.22	- .20
9	-1.11	- .36	.21	-2.33	- .89	.02	- .33	- .09	- .10	- .39
10	.21	.15	.34	.00	.06	.19	.20	.28	.11	.33
11	- .80	- .99	- .81	- .77	- .18	.19	- .14	- .11	- .20	.15
12	-1.10	- .80	- .76	- .37	- .87	- .25	-1.04	- .23	- .29	- .18
13	.31	.41	.27	.27	.37	.35	.09	.01	.04	.27
14	- .44	.64	- .78	- .39	.00	- .05	.16	.04	.59	- .21
15	.13	- .37	.18	- .60	-1.27	- .64	.08	.54	.02	- .37
16	.15	.26	.21	.33	.27	.26	.09	.33	.20	.00
17	-1.09	- .22	.23	-1.06	-1.23	.47	- .34	.30	.12	.03
18	.51	- .08	-1.68	-1.57	-1.71	.00	.03	.07	- .18	.29
19	1.29	.23	.76	.06	- .22	.22	.35	.25	.18	.01
20	- .39	- .59	.04	.09	- .27	- .43	- .12	.16	.10	.19
21	-1.82	-1.04	-1.21	-1.29	-1.72	- .91	- .56	.40	-1.19	- .56
22	.09	.18	.14	.39	.07	.04	.16	.06	- .02	.13
23	- .22	.12	- .56	- .62	- .31	.12	- .24	.13	.10	.33
24	-1.58	- .64	- .50	- .88	-2.52	-1.23	.26	.21	- .06	- .01
25	.23	.27	.11	.14	.21	.01	.03	.13	.10	.05
26	- .50	.13	.08	.58	- .12	.46	- .07	- .10	.13	- .54
27	- .61	.70	-1.59	- .04	-1.29	-1.02	-1.12	- .20	- .71	- .42

SUBJECT IV

DIFFERENCE BETWEEN ACTUAL STIMULUS DURATION AND SUBJECT RESPONSE

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	.31	.21	- .16	.09	.07	- .06	- .06	- .26	- .01	- .12
2	- .93	- .69	.02	.49	- .64	- .38	- .86	- .24	- .72	- .51
3	-1.17	-1.33	- .83	.16	- .63	-1.37	- .88	-1.20	1.18	- .24
4	.05	- .06	.04	.04	- .21	- .10	- .03	- .10	.03	- .05
5	- .72	- .08	.19	- .76	- .58	.28	.27	- .01	.07	.05
6	-1.58	-2.49	-1.50	-1.80	-2.63	- .35	-1.54	-1.13	- .90	-1.57
7	.13	.04	- .05	.02	.15	.12	- .10	- .05	- .08	.09
8	- .11	-1.33	.72	-1.06	- .67	.47	- .78	.23	.86	.10
9	-1.79	.61	-1.45	- .45	-1.17	-1.07	-1.36	- .61	1.20	- .42
10	.01	.00	.01	.06	- .21	.02	- .13	.00	.03	.06
11	- .15	.58	- .21	-1.03	- .29	.02	- .70	-1.39	- .38	- .60
12	-1.46	-1.99	-2.28	-1.48	3.25	-1.26	-2.41	-1.83	.04	-1.70
13	.10	.15	.14	.00	.22	.16	- .17	- .07	- .02	- .04
14	.18	- .48	- .80	- .11	- .59	- .42	- .61	- .70	- .21	- .17
15	- .61	.44	.24	-1.39	-1.58	- .17	-1.07	-1.68	-1.33	-1.76
16	.00	.10	.13	.03	.10	.22	.07	.04	.03	- .16
17	.17	- .87	- .11	- .64	- .64	- .18	- .25	- .54	- .53	- .42
18	-1.60	- .60	-2.20	.01	- .73	1.04	-1.86	-2.15	- .95	-1.22
19	.56	.20	.30	.32	.34	.00	.05	- .02	.18	.16
20	- .73	- .26	.18	- .51	- .28	.53	- .38	-1.67	.35	-1.51
21	-1.18	- .60	- .57	.50	-2.91	-1.00	-1.82	-1.27	- .49	-1.95
22	- .03	- .70	.13	- .06	.41	- .13	- .04	- .07	.03	.20
23	.27	.01	- .10	- .87	-1.31	- .85	- .33	- .10	.17	- .58
24	-1.62	- .39	-1.23	- .80	-2.49	1.17	-2.34	- .27	.54	-1.33
25	.14	- .10	.00	.02	.34	- .03	.01	.00	.08	.07
26	- .44	.03	- .96	- .71	- .16	.04	- .14	- .48	-1.08	- .65
27	- .45	-1.14	- .54	- .36	-3.72	- .83	-2.59	- .73	-1.11	-1.53

SUBJECT V

DIFFERENCE BETWEEN ACTUAL STIMULUS DURATION AND SUBJECT RESPONSE

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	.08	.13	.00	- .04	- .04	.02	- .04	- .09	.01	.01
2	- .73	.13	- .02	.39	- .74	- .60	- .19	- .44	- .70	- .31
3	1.55	- .03	- .18	.13	-1.74	.49	- .45	.03	- .31	- .04
4	.06	.04	.05	.27	.12	- .01	.11	.01	.11	.00
5	- .56	.07	.01	- .38	.04	- .42	.06	.04	.44	- .72
6	- .38	- .62	.52	- .57	-1.14	.35	.05	.67	- .20	- .20
7	- .06	- .11	.01	- .17	.08	.08	- .08	- .05	.08	- .02
8	- .24	- .37	- .42	.77	.03	- .34	- .64	- .52	.08	- .64
9	- .22	- .10	.27	.85	- .90	- .13	- .03	- .09	.07	- .39
10	.05	.00	- .09	.07	- .19	.06	.20	- .05	- .08	.02
11	- .61	- .21	- .48	.09	- .71	- .43	- .57	.03	- .19	- .43
12	- .95	.42	- .31	- .10	- .48	- .38	-1.02	- .38	- .40	- .47
13	.04	- .02	.15	.24	.16	.06	- .01	- .04	.06	.01
14	- .48	- .10	.20	- .28	- .68	- .36	- .22	- .60	- .31	- .44
15	-1.04	- .99	.44	.63	-1.23	.32	- .52	- .38	.00	- .66
16	- .03	- .12	.05	.08	.08	- .01	- .11	.05	.16	.21
17	-1.10	- .25	.08	- .33	-1.08	- .03	- .29	- .47	- .49	- .28
18	-1.16	.04	.44	1.05	-1.16	- .78	- .37	-1.04	.11	- .07
19	.16	.06	- .10	- .11	.23	.03	.02	.02	.06	.07
20	- .61	- .67	.51	- .08	.18	- .81	- .10	.01	- .30	- .51
21	- .09	- .23	.52	- .17	- .15	- .13	- .55	- .45	.06	- .26
22	- .07	- .14	.09	- .09	- .09	- .11	- .11	.26	.10	- .03
23	- .64	- .05	.27	.08	- .52	- .37	- .16	- .26	.27	- .81
24	- .74	- .54	- .10	.43	- .65	- .45	- .27	- .02	.54	- .70
25	- .03	.19	- .02	- .03	.16	- .14	- .08	- .05	- .09	.03
26	- .07	- .49	.09	.22	- .02	- .16	- .53	.20	- .41	- .68
27	-1.10	.19	- .47	- .77	-1.45	.08	- .36	- .87	- .38	- .35

APPENDIX B

SUBJECT I

DIFFERENCE-TIME RATIO

PRESENTATION NUMBER

	1	2	3	4	5	6	7	8	9	10
1	+.0300	-.0900	-.0792	+.1900	+.1100	-.0700	+.0100	-.0495	+.1900	-.1100
2	-.0721	-.2240	-.2000	-.2620	+.0121	-.0421	-.2280	-.0440	-.0300	-.0800
3	-.1743	-.3026	-.2803	-.2278	-.1822	-.1441	-.1268	-.1368	+.1733	-.1200
4	+.0200	+.0200	-.1188	-.0198	-.0600	-.0300	-.0800	+.0099	-.3465	-.1900
5	-.0061	-.1804	-.1260	-.1280	-.1360	-.0667	-.1202	-.1060	-.0940	-.0520
6	-.2024	-.2728	-.2889	-.1815	-.2178	-.2592	-.1949	+.0556	+.0434	-.0356
7	+.0100	+.1782	+.3168	-.1100	+.0500	+.0000	-.0099	+.1188	-.1600	+.1600
8	-.1946	-.1680	-.2265	-.3180	-.1762	-.2289	-.0880	+.0220	+.1620	-.0361
9	-.2678	-.3081	-.2244	+.2341	-.1778	-.0844	-.2692	-.1344	-.1371	-.3034
10	+.9802	+.7030	+.8416	+.3600	-.2500	+.5149	+.8416	+.3960	-.4700	+.4100
11	-.0730	-.0440	-.0220	-.1804	-.0401	-.0301	-.1200	+.0450	-.0040	+.0040
12	-.2091	-.1757	-.1789	-.5595	-.2339	-.0334	-.1379	-.2100	-.1969	-.1537
13	+.0200	+.1287	-.3168	-.1800	-.2100	+.0500	+.0594	+.2277	+.0400	+.1800
14	-.2164	-.3160	-.1437	-.0720	-.0481	-.2505	-.0100	+.1936	+.0620	-.1463
15	-.0756	-.2992	-.2511	-.1258	-.0590	-.2503	-.3237	-.0178	-.1403	+.1313
16	+.2100	+.2673	+.1782	+.0900	-.0500	-.0600	-.0495	+.0990	+.1100	+.1600
17	-.0902	-.0780	-.0301	+.0080	-.1400	-.1784	-.1300	+.1142	-.1560	-.0940
18	-.0311	-.4388	-.2344	-.4194	-.0144	+.0056	-.1325	-.0878	-.1980	-.1656
19	+.2079	+.1584	+.1188	+.0600	+.1000	+.1683	-.0693	-.0891	+.1000	-.2100
20	-.1082	+.1062	-.0220	-.1058	-.2000	+.0341	+.0341	+.0380	-.0419	-.0220
21	-.1974	-.0200	-.1613	-.1214	-.1824	-.1676	-.1935	-.1313	-.1437	-.0645
22	+.2200	+.1980	+.1400	+.1600	+.0900	+.2200	+.1485	+.2200	+.1700	+.0300
23	-.1283	-.1956	-.0880	-.0902	-.1078	+.1042	-.0160	+.0840	-.0321	-.0080
24	-.1233	-.2633	-.2280	-.2339	-.1769	-.2956	-.3778	-.2403	-.2127	-.2002
25	+.0198	+.2500	+.0099	+.2400	+.0700	+.0000	-.0700	+.2079	+.0900	+.2200
26	-.1303	-.0660	-.1160	-.1320	-.1380	-.0701	-.2000	-.0680	-.0140	-.2260
27	-.3003	-.2194	-.4044	-.2158	-.3326	-.1980	-.1915	-.6622	-.0612	-.2436

SUBJECT II

DIFFERENCE-TIME RATIO

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	-.0400	+.3600	+.1881	+.3800	-.1800	-.0200	-.1200	+.1089	+.1100	-.0100
2	-.0301	-.1240	-.1060	-.0520	-.0620	-.1784	-.1840	-.1100	-.0800	-.0860
3	-.0034	-.0412	-.0501	-.1344	-.0956	-.1588	-.0723	-.0200	-.0122	-.1122
4	+.1600	-.2400	-.1485	+.6733	-.1900	+.0600	+.0600	+.0495	+.0693	+.1200
5	-.1192	+.1303	-.0860	-.0540	-.1360	-.0970	-.1042	-.1960	-.0240	-.1260
6	-.0423	-.0952	-.1744	-.1136	+.0122	-.0712	-.1303	+.0056	-.1102	-.0033
7	+.0000	+.1980	+.1782	-.1100	+.1000	-.2200	-.0990	+.1980	+.1600	-.0600
8	-.0602	-.0560	-.0822	+.0580	-.0842	+.0000	-.0460	-.0641	-.0960	-.0641
9	-.1956	-.0712	-.0522	-.1371	-.0689	-.0200	-.0623	-.1000	-.0803	+.0078
10	+.2079	+.1782	+.0297	+.0800	-.2100	+.0495	+.1485	-.1386	-.0400	-.2200
11	+.1185	-.0060	-.0740	-.0261	-.0561	-.1064	-.1520	-.0860	-.0982	-.0822
12	-.0501	-.0423	-.0544	-.0634	-.0156	-.0367	-.0979	-.0867	-.1713	-.0457
13	-.2200	+.1782	-.0891	-.0100	-.2600	+.1500	+.0594	-.1881	-.1900	-.0600
14	-.1242	+.0620	-.1158	-.0860	-.0401	-.0020	+.0100	-.1277	-.0480	-.0762
15	-.0723	-.0011	+.0900	-.0156	+.1001	-.1023	-.0667	-.0933	-.1114	-.0033
16	+.2200	+.2673	+.0792	+.1100	-.1200	+.0400	-.0099	+.1485	+.0800	+.1900
17	+.0020	-.0100	-.1222	-.0440	-.0920	-.1663	-.0800	-.0361	-.0320	-.1040
18	-.1400	-.0880	+.0267	-.1446	-.0744	-.0844	-.1013	-.0767	+.1089	-.0733
19	+.1287	+.1980	-.0198	+.0000	-.1200	+.0099	-.0099	+.0297	+.1900	-.1400
20	+.1453	-.0140	-.0080	+.0160	-.0580	-.0561	-.0100	-.1080	+.0140	-.0540
21	-.0088	-.0877	-.1123	-.0913	+.0323	-.0209	-.0690	-.0857	-.0935	-.0868
22	+.1800	+.1683	+.0200	+.2400	-.0600	+.1800	-.0297	-.0400	-.0200	+.0400
23	-.0361	-.0599	-.0620	+.1363	-.0838	-.1804	-.1836	+.0380	-.0862	-.1038
24	-.0122	-.0889	-.0478	-.0635	-.0423	-.0233	-.0678	-.0467	-.0089	-.0790
25	+.0396	+.2700	+.0099	+.1100	-.1100	-.0495	+.0600	-.0099	+.1100	+.0300
26	-.0601	-.0060	+.0620	-.0180	-.0520	-.0922	+.0780	+.0740	-.0580	-.1780
27	-.0473	+.0134	+.0156	-.0645	-.0300	-.0389	-.0501	-.0533	-.0556	-.0367

SUBJECT III

DIFFERENCE-TIME RATIO

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	+.1400	+.3100	+.0495	+.2800	+.0400	+.2300	+.2800	+.0891	+.2500	+.1800
2	+.0080	+.0000	+.0580	+.0000	-.0280	+.0301	-.0160	+.0080	-.0380	+.0040
3	+.0994	-.0623	+.0100	+.0000	+.1933	-.0402	+.0145	+.0654	-.0878	+.0544
4	+.3900	+.2400	+.2475	+.6733	+.2200	+.1200	+.3500	+.1386	+.2772	+.2100
5	-.1010	+.1383	+.1880	-.0480	-.2320	+.0424	+.0020	+.1000	-.1140	-.0180
6	+.0067	-.0713	-.0544	-.1247	-.0300	-.0300	-.0590	-.1278	-.1459	+.0189
7	+.2100	+.3366	+.3069	+.3000	+.0900	+.0400	+.0792	+.1188	+.1300	+.1200
8	-.0120	-.0380	+.0401	-.2080	+.2285	+.0362	+.1180	+.0581	+.0440	-.0401
9	-.1233	-.0400	+.0233	-.2589	-.0989	+.0022	-.0367	-.0100	+.0111	-.0433
10	+.2079	+.1485	+.3366	+.0000	+.0600	+.1881	+.1980	+.2772	+.1100	+.3300
11	-.1606	-.1980	-.1620	-.1543	-.0361	+.0382	-.0156	-.0220	-.0401	+.0301
12	-.1224	-.0890	-.0844	-.0412	-.0969	+.0278	-.1157	-.0256	-.0323	-.0200
13	+.3100	+.4059	+.2673	+.2700	+.3700	+.3500	+.0891	+.0099	+.0400	+.2700
14	-.0882	+.1280	-.1557	-.0780	+.0000	-.0100	+.0320	+.0080	+.1180	-.0424
15	+.0145	+.0412	+.0200	-.0668	-.1413	-.0712	+.0089	+.0600	+.0022	-.0412
16	+.1500	+.2574	+.2079	+.3300	+.2700	+.2600	+.0891	+.3267	+.2000	+.0000
17	-.2184	-.0440	+.0461	-.2120	-.2460	+.0942	-.0680	+.0601	+.0240	+.0060
18	+.0567	-.0089	-.1867	-.1746	+.1900	+.0000	+.0033	+.0078	-.0200	+.0322
19	-.0495	+.2277	+.7525	+.0600	+.2200	+.2178	+.3465	+.2475	+.1800	+.0100
20	-.0782	-.1182	+.0080	+.0180	-.0540	-.0862	-.0240	+.0320	+.0200	+.0380
21	-.2007	-.1157	-.1346	-.1437	-.1913	-.1003	-.2024	+.0445	-.1235	-.0623
22	+.0900	+.1782	+.1400	+.3900	+.0700	+.0400	+.1584	+.0600	-.0200	+.1300
23	-.0441	+.0240	-.1120	-.1242	-.0619	+.0240	-.0479	+.0260	+.0200	+.0659
24	-.1756	-.0711	-.0556	-.0980	-.2803	-.1367	+.0289	+.0234	-.0067	-.0011
25	+.2277	+.2700	+.1089	+.1400	+.2100	+.0099	+.0300	+.1287	+.1000	+.0500
26	- .1002	+.0260	+.0160	-.1160	-.0240	+.0922	-.0140	-.0200	+.0260	-.1080
27	-.0679	+.0668	-.1767	-.0044	-.1435	-.1135	-.2361	-.0222	-.0790	-.0467

SUBJECT IV

DIFFERENCE-TIME RATIO

PRESENTATION NUMBER

	1	2	3	4	5	6	7	8	9	10
1	+.3100	+.2100	-.1584	+.0900	+.0700	-.0600	-.0600	-.2574	-.0100	-.1200
2	+.1864	-.1380	+.0040	+.0980	-.1280	+.0762	-.1720	-.0480	-.1440	-.1020
3	-.1307	-.1479	-.0923	+.0178	-.0700	-.1531	-.0979	-.1355	+.1311	-.0267
4	+.0500	-.0600	+.0396	+.0396	-.2100	-.1000	-.0300	-.0990	+.0297	-.0500
5	-.1455	-.0160	+.1380	-.1520	-.1160	+.0566	+.0541	-.0020	+.0140	+.0100
6	-.1758	-.2773	+.1667	-.2004	-.2922	-.0389	-.1715	-.1256	+.1002	-.1744
7	+.1300	+.0396	-.0495	+.0200	+.1500	+.1200	-.0990	-.0495	-.0800	+.0900
8	-.0221	-.2660	+.1443	-.2120	-.1343	+.0944	-.1560	+.0461	+.1720	+.0200
9	-.1989	+.0679	-.1611	+.0502	-.1300	-.1189	-.1513	-.0678	+.1338	-.0467
10	+.0099	+.0000	+.0099	+.0600	-.2100	+.0198	-.1287	+.0000	+.0300	+.0600
11	-.0301	+.1160	-.0420	-.2064	-.0581	+.0040	-.1400	-.2780	-.1663	-.1202
12	-.1624	-.2214	-.2533	-.1646	-.3619	-.1402	-.2680	-.2033	+.0044	-.1893
13	+.1000	+.1485	+.1386	+.0000	+.2200	+.1600	-.1683	-.0693	-.0200	-.0400
14	+.0361	-.0960	-.1597	-.0220	-.1182	-.0842	-.1220	-.1397	-.0420	-.0341
15	-.0679	+.0489	+.0267	-.1548	-.3020	-.0189	-.1990	-.1867	-.1481	-.1958
16	+.0000	+.0900	+.1287	+.0300	+.1000	+.2200	+.0693	+.0396	+.0300	-.1600
17	+.0341	-.1740	-.0220	-.1280	-.1280	-.0361	-.0500	-.1082	-.1060	-.0840
18	-.0667	-.0668	-.2444	+.0011	-.0811	+.1156	-.2084	-.2389	-.1057	-.1356
19	+.5545	+.1980	+.2970	+.3200	+.3400	+.0000	-.0495	-.0198	+.1800	+.1600
20	-.1463	-.0541	+.0360	-.1018	-.0560	-.1062	-.0762	+.3340	+.0699	-.3020
21	-.1301	-.0667	-.0634	+.0557	-.3237	-.1103	+.2024	-.1413	-.0546	-.2169
22	-.0300	-.1980	+.1300	-.0600	+.5100	-.1300	-.0396	-.0700	+.0300	+.2000
23	+.0541	+.0020	-.0200	-.1743	-.2615	-.1703	-.0659	+.0200	+.0341	-.1158
24	-.1800	-.0433	+.1368	+.0891	-.2770	-.1300	-.2600	-.0300	-.0601	-.1479
25	+.1386	-.1000	+.0000	+.0200	+.3400	-.0297	+.0100	+.0000	+.0800	+.0700
26	-.0882	+.0060	-.1920	-.1420	-.0320	+.0080	-.0280	-.0960	-.2160	-.1300
27	-.0501	-.1381	-.0600	-.0400	-.4138	-.0923	-.2884	-.0811	-.1235	-.1702

SUBJECT V

DIFFERENCE-TIME RATIO

	PRESENTATION NUMBER									
	1	2	3	4	5	6	7	8	9	10
1	+.0800	+.1300	+.0000	-.0400	+.0400	+.0200	-.0400	-.0891	+.0100	+.0100
2	-.1463	+.0260	-.0040	+.0780	-.1480	-.1202	-.0380	-.0880	-.1400	-.0620
3	+.1732	-.0501	-.0200	+.0144	-.1933	+.0547	-.0501	-.0033	-.0344	-.0044
4	+.0600	+.0400	+.0495	+.2673	+.1200	-.0100	+.1100	+.0099	+.1089	+.0000
5	-.1131	+.0140	+.0020	-.0760	+.0080	-.0848	-.0120	+.0080	-.0880	-.1440
6	-.0423	-.0680	+.0578	-.0635	-.1267	+.0389	+.0056	+.0744	-.0223	+.0222
7	-.0660	-.1089	+.0099	-.1700	+.0800	+.0800	-.0792	-.0495	+.0800	-.0200
8	-.0482	-.0740	-.0842	+.1320	+.0060	-.0683	-.1280	-.1042	+.0160	-.1283
9	-.0244	-.0111	+.0300	+.0948	-.1000	-.0144	-.0033	-.0100	+.0078	-.0433
10	+.0495	+.0000	-.0891	+.0700	-.1900	+.0594	+.1980	-.0495	-.0800	+.0200
11	-.1225	-.0420	-.0960	+.0180	-.1423	-.0863	-.1140	+.0060	-.0381	-.0862
12	-.1057	-.0476	-.0344	-.0111	-.0535	-.0423	-.1135	-.0422	-.0445	-.0523
13	+.0400	-.0198	+.1485	+.2400	+.1600	+.0600	-.0099	-.0396	+.0600	+.0100
14	+.0962	-.0200	+.0399	-.0560	-.1363	-.0721	-.0440	-.1198	-.0620	-.0882
15	-.1157	-.1101	+.0489	+.0702	-.1368	+.0356	-.0578	-.0422	+.0000	-.0734
16	-.0300	-.1188	+.0495	-.0800	+.0100	+.1089	-.0495	+.1600	+.1600	+.2100
17	-.2204	-.0500	+.0160	-.0660	-.2160	-.0060	-.0580	-.0942	-.0980	-.0560
18	-.1289	+.0045	+.0489	+.1168	-.1289	-.0867	-.0412	-.1156	+.0122	-.0078
19	+.1584	+.0594	-.0990	-.1100	+.2300	+.0297	+.0198	+.0198	+.0600	+.0700
20	-.1222	-.1343	+.1020	-.0160	+.0360	-.1623	-.0200	+.0020	-.0599	-.1020
21	-.0099	-.0256	+.0578	-.0189	-.0167	-.0143	-.0612	-.0501	+.0067	-.0289
22	-.0700	-.1386	+.0900	+.0479	-.0900	-.1100	-.1089	+.2600	+.1000	-.0300
23	-.1283	-.0100	+.0520	+.0160	-.1038	-.0741	-.0319	-.0520	+.0541	-.1617
24	-.0822	-.0600	+.0111	-.0900	-.0723	-.0500	-.0300	-.0022	+.0601	-.0779
25	-.0297	+.1900	-.0198	-.0300	+.1600	-.1386	-.0800	+.0495	-.0900	+.0300
26	-.0140	-.0980	+.0180	+.0440	-.0040	-.0321	-.1060	+.0580	-.0820	-.1360
27	-.1224	+.0212	-.0522	-.0857	-.1613	+.0889	-.0401	-.0966	-.0423	-.0389

APPENDIX C

Good evening. This is Mr. Hartbauer calling from the department of Speech at Michigan State University. I have been given permission by Dr. Oyer, the director of the Speech and Hearing Clinic, to contact you and request your cooperation on a research project. This would require about three hours of your time some evening next week, at the Speech and Hearing Research Laboratory.

You would be paid one dollar an hour for your help. Your task would be simple. It only involves listening to various tones. You would be asked to make judgments concerning them. Your assistance on this project would be of great benefit to us and to persons who are hard of hearing. Is there any certain night, Sunday through Thursday, that would fit best into your schedule? Would it be more convenient for you to come at 6:00 or at 7:00 on that evening? Would you prefer to have transportation provided for you?

TEXT OF TELEPHONE SOLICITATION
FOR SUBJECT PARTICIPATION

APPENDIX D

CENTRAL INSTITUTE FOR THE DEAF

818 SOUTH EUCLID

DR. MAX A. GOLDSTEIN, FOUNDER

ORAL SCHOOL FOR DEAF CHILDREN
SCHOOL FOR CHILDREN WITH HEARING, SPEECH, AND LANGUAGE DISORDERS

TEACHERS' COLLEGE
RESEARCH LABORATORIES
SPEECH AND HEARING CLINICS

S. RICHARD SILVERMAN, PH. D., DIRECTOR

HELEN S. LANE, PH. D., PRINCIPAL
HALLOWELL DAVIS, M. D., DIRECTOR OF RESEARCH

ST. LOUIS, MO., 63110
March 1, 1966

Mr. R. E. Hartbauer, Chairman
Speech Department
Walla Walla College
College Place, Washington 99324

Dear Mr. Hartbauer:

In reply to your letter of 23 February 1966, I must confess that I know of no reference in which the perception of the duration of sounds by hard of hearing persons has been published. The role of frequency or loudness in the perception of auditory duration has not been investigated very thoroughly either but I am sure that you will find appropriate references in the chapter on Time Perception by Woodrow in Handbook of Experimental Psychology (Ed. S. S. Stevens), 1951, New York, John Wiley; and also in the new English translation called The Psychology of Time by Paul Fraisse, published by Harper and Row, New York. Finally, I am enclosing a reprint of an article that we published some years ago on the effects of auditory as opposed to visual ambient stimulation on the perception of duration. I hope that the above is of some use.

Sincerely yours,

Ira J. Hirsh
Director of Research

IJH/ezl
Encl.

THE UNIVERSITY OF MICHIGAN
MEDICAL SCHOOL
ANN ARBOR

KRESGE HEARING RESEARCH INSTITUTE
MERLE LAWRENCE, PH.D., DIRECTOR

March 7, 1966

Mr. R. E. Hartbauer
Chairman
Speech Department
Walla Walla College
College Place, Washington 99324

Dear Mr. Hartbauer:

Dr. Lawrence referred your question concerning the effects of signal duration among the hearing impaired. A literature search on this topic might begin by looking in the various abstracts under such key words as "temporal integration", "brief-tone audiometry", the "Bunson-Roscoe Law", etc. In addition, here are two articles to get you started:

(1) Simon, G.R., The critical Bandwidth Level in Recruiting Ears and its Relation to Temporal Summation, Jour. Auditory Res. 3:109-119, 1963.
This is a dissertation done under Dr. R. Bilger - you might write him for further information.

(2) Harris, J.E., et al., Brief tone audiometry: temporal integration in the hypacusic, Arch. Otolaryng., 67:699-713, 1958.

Sincerely,

Dean Clack

T. Dean Clack

TDC:lp

RESEARCH INSTITUTE
HOUSTON SPEECH AND HEARING CENTER

1343 MOURSUND AVENUE, HOUSTON, TEXAS 77025 • JA 4-3136 • TEXAS MEDICAL CENTER

Director of Research, JAMES JERGER, Ph.D.

JACK L. BANGS, Ph.D.
Executive Director

TINA E. BANGS, Ph.D.
Associate Director

March 2, 1966

R. E. Hartbauer
Speech Department
Walla Walla College
College Place, Washington 99324

Dear Mr. Hartbauer:

The only person that I know of who has considered the problem of duration perception in the hearing-impaired is Dr. Howard Ruhm. His complete address is:

Dr. Howard Ruhm
Speech & Hearing Clinic
University of Oklahoma Medical Center
Oklahoma City, Oklahoma

I'm sure that, if you will write directly to him he can put you in touch with the literature you seek. I have taken the liberty of forwarding your letter to him.

Sincerely,

James Jerger

James Jerger, Ph.D.
Director of Research

JJ:re
Enc.
cc: Dr. Howard Ruhm

THE UNIVERSITY OF MICHIGAN
MEDICAL SCHOOL
ANN ARBOR

KRESGE HEARING RESEARCH INSTITUTE
MERLE LAWRENCE, PH.D., DIRECTOR

March 3, 1966

Mr. R. E. Hartbauer
Chairman
Speech Department
Walla Walla College
Colege Place, Washington 99324

Dear Mr. Hartbauer:

Right off hand I have no information on the effects of duration, frequency and loudness on perception of duration of sounds in persons with hearing impairment. However, I am taking the liberty of turning your letter over to Dr. Dean Clack of our Institute, who is familiar with this kind of literature and may be able to help you.

Sincerely yours,

Merle Lawrence

Merle Lawrence

ML:fm

SPEECH AND HEARING CENTER

THE UNIVERSITY OF OKLAHOMA
MEDICAL CENTER
825 NORTHEAST FOURTEENTH STREET
OKLAHOMA CITY, OKLAHOMA 73104

March 10, 1966

R. E. Hartbauer, Chairman
Speech Department
Walla Walla College
College Place, Washington 99324

Dear Mr. Hartbauer:

I know of no work concerned with discrimination of acoustic duration in abnormal subjects other than the study done by Dr. William A. Cooper under my direction.

Dr. Cooper's work can be obtained in the form of a doctoral dissertation entitled "The Effect of a Cochlear Pathology on the Difference Limen for Duration", University of Oklahoma, 1964. A less detailed version of Dr. Cooper's experiment is presented along with two foregoing experiments on normal subjects in a manuscript submitted to the Journal of Speech and Hearing Research. This article should be published in the next issue of that Journal. I will send you two reprints as soon as they are available.

An excellent review of the literature in the field of duration discrimination can be found either in Dr. Cooper's dissertation or in the dissertations by Dr. Eugene O. Mencke, "Monaural Differential Sensitivity for Short Stimulus Duration", 1963, and Dr. Braxton Milburn, "Differential Sensitivity to Duration of Monaural Pure-Tone Auditory Stimuli", 1963, both done at the University of Oklahoma Medical Center.

If I can be of further service to you, please let me know.

Sincerely,

Howard B. Ruhm, Ph.D.
Director of Audiological Research

HBR:ls

APPENDIX E

DEPARTMENT OF SPEECH

WALLA WALLA COLLEGE

COLLEGE PLACE
WASHINGTON 99324

9 January 1966

Dear Dr. ____________________:

As part of my Ph. D. program at Michigan State University I am writing a dissertation on the effects of duration, frequency, and loudness on perception of duration of sounds. To date I have been unable to find any literature on the way in which hearing impaired perceive duration. Dr. Herbert Oyer, my major professor, encouraged my contacting you requesting your directing me to any such research of which you may know.

Very sincerely,

R. E. Hartbauer
Chairman

crc