THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS UPON THE REPRODUCTION OF TEMPORAL INTERVALS

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ABSTRACT

THE EFFECTS OF DURATION, FREQUENCY, AND LOUDNESS UPON THE REPRODUCTION OF TEMPORAL INTERVALS

by Leo V. Deal

Interest in the nature of time has concerned mankind for hundreds of years. When the study of time moved into the laboratory in the middle of the nineteenth century, the manner in which man perceives time was stressed. Since that time several approaches have been taken in an attempt to describe man's temporal perception.

Contradictory findings have been reported regarding the effects of the acoustic stimuli filling a temporal interval. The purpose of this study was to explore the effects of duration, frequency, and loudness upon the interpretation of time. Five durations (1, 3, 5, 7, and 9 seconds), five frequencies (250, 500, 1000, 2000, and 4000 cycles per second), and five loudness levels (40, 50, 60, 70, and 80 phons) were chosen as stimulus parameters. One-hundred and twenty-five different combinations of these parameters were possible, and each was placed on magnetic tape in a randomized fashion. Using the psycho-physical method of reproduction, five normal hearing

subjects heard the series of 125 stimuli and reproduced each temporal interval by depressing a telegraph key. During the response the subject heard the same frequency and the same loudness level that was present in the stimulus interval.

The reproductions were transformed into the ratio $\Delta T/T$, where ΔT represents the difference-time between the stimulus duration and the duration of the reproduction and $\underline{T}$ represents the stimulus duration. When an interval was overestimated, the ratio was positive; when an interval was underestimated, the ratio was negative. Each subject judged different randomizations of the stimuli until on two consecutive days he showed no significant difference between means and a correlation of at least +.90. The mean of the last two sessions was considered as that subject's score for each particular combination of duration, frequency, and loudness.

An F-Max test indicated that there was a lack of homogeneity of variance for each of the three stimulus parameters; however, the finding that heterogeneity of variance does not necessarily adversely affect the results allowed the experimenter to treat the data by an analysis of variance. It was found that neither frequency nor loudness had any significant effect upon the ability of subjects to reproduce durations. There were no interactions between or among the three stimulus parameters. The only variable that affected the reproductions was duration. Utilizing a critical difference test, it was found that differences existed between every possible combination of durations.

On the basis of the results it was concluded that neither frequency nor loudness of a stimulus affects a subject's ability to reproduce durations. Reproduction of temporal intervals is affected by the duration of the stimulus. On the average, the durations of one and three seconds were overestimated and the durations of seven and nine seconds were underestimated; the five second interval was neither overestimated or underestimated.

The curve representing the ratio $\Delta T/T$ is relatively linear from a positive ratio for one and three seconds through an indifference point near five seconds to a negative ratio for seven and nine seconds. It was concluded that Weber's Law did not hold in this study.

The obtained indifference interval of 4.90 seconds fell very near the middle of the range of durations used, a fact indicating there was a central tendency factor functioning in this experiment. It was also found that serial position in the series had no effect upon the reproductions of the stimulus durations.

On the basis of the results, recommendations were made for further research.

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By

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CHAPTER I

INTRODUCTION

The problem of the nature of <u>time</u> is one that has confounded and confused manking for centuries. Upon surveying the literature on time, one is amazed by the contradiction and confusion that exist. Sturt[1] states that authors discussing time from different fields have hampered or even ignored each other; this leads to more confusion. One popular expression states that "Time stood still;" but another suggests that "Time waits for no one." These are extremes that are also to be found in the literature regarding the nature of <u>time</u>. The confusion over the nature of time is not surprising, for studies of time have come from many different fields.

Gilliland, Hofeld, and Eckstrand[2] point out that the philosopher is interested in the nature of time, the physicist and the astronomer are interested in the accurate measurement of time, the daily worker is concerned about

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

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

the time-clock, the athlete is interested in competing with the clock, and the aviator must be concerned about time in his maneuvers. One could add more areas in which the study of and an interest in time are important. The psychologist, of course, is interested in how people respond to time. The sociologist is interested in what people do with their time, especially the teen-ager and the aged.

The general population, even though people may not have stopped to consider it, is greatly influenced by time. Some people are compulsive about arriving at their destinations on time; some are never late for an appointment. On the other hand, some people never seem to be concerned about adjusting to the time of others; they seem to have little concept of "being on time."

According to Fraisse,[3] philosophers studying the origin of the idea of time have concluded that it comes from change. He then asks an interesting question: What changes? Our sensations or our thoughts? The answers to these questions are going to be different depending upon who answers them.

Rhythmic change can also give us some concept of time. Fraisse reminds us that scientists have been studying

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

[2]*Ibid.*, p. 2.

periodic phenomena--such as day and night, the lunar cycle, the annual recurrence of seasons--for thousands of years and trying to relate them to each other. We are reminded that people are still perfecting methods of measuring time and that reform of the calendar is on the agenda of the United Nations.

One method for measuring time that has been used for centuries has been in the earth's rotation. Bell and Bell explain the process:

> One complete rotation of the earth can be exactly determined by recording the instant a certain point on the earth--such as the meridian at the Royal Observatory at Greenwich, England, or at the Naval Observatory in Washington, D. C.--passes under a certain star on one night and again on the following night. The interval between two passes defines one revolution of the earth, or one day. This interval of time can then be theoretically divided into 86,400 equal parts, each of which represents the length of a second in time.[5]

These authors do point out, however, that the earth is not a reliable timekeeper, for it may gain or lose small fractions of time. The reason for this lack of stability is that the earth tends to wobble on its axis of rotation and the speed of the earth is not constant as it moves in its slightly elliptical orbit around the sun.[6]

This instability of the earth has caused the International Bureau of Weights and Measures to discuss the

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

[6]*Ibid.*

adoption of a new official standard for measuring a second. A recent popular article[7] points our that a second used to be 1/60th of a minute, or 1.3600th of an hour, of 1/86400th or a day. These measurements are made with the assumption that the earth rotates on its axis once every 24 hours. The unevenness, the erratic spin of the earth has caused the earth to speed up, to slow down, and then to speed up again. Since the physical measurement of time cannot be reliably determined, it is not surprising, then, that the measurement of psychological time is also difficult to measure.

The exactness of the physical measures of time would probably lead most people to believe that we are close to the determination of what time is. There is one slight problem, however: Bell and Bell tell us that ". . .neither clock nor calendar really represents time itself. These two inventions are only a means of reckoning and recording the passage of time."[8] We would have to agree that these are only representations of time, for certainly man felt the passage of time long before there were instruments to measure it. Cohen[9] states that primitive

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[7] Time, September 11, 1964, p. 85.

[8] Bell and Bell, op. cit., p. 12.

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

peoples customarily measure time in terms of social events and tasks, not in units of duration. He stresses that the value placed on intervals of time varies with social or economic pressures.

Is time, then, something that can be measured? Is it an objective phenomenon? Or is it, as Sturt suggests, a "concept which is built up through individual and racial experience?"[10] If it is, then time is subjective, something that is created in our own minds, not something that objectively exists. Weber also discusses the problem of subjective and objective dichotomy of time:

> The accurate and highly developed physical instruments which are to be had for the measurement of time, for example, afford us a useful method of approaching problems of experiential time. The danger of this dichotomy lies in the tendency to assume unwittingly that objective time alone is real and to disregard the conditions of experiential time which give rise to the deviations from the objective time schemes.[11]

In his excellent review of the literature Weber points out that the Newtonian concept of time was that there was one homogeneous and impersonal duration--a mechanistic idea of time. Other scientists have rejected the idea of a mechanistic time and assume a "multiplicity of durations, each flowing at a different rate from one individual to another, and at different rates under different conditions...."[12]

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[10] Sturt, op. cit., p. 2.

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

[12] Ibid., p. 235.

Empirically, it would seem that we would have to reject the mechanistic view of time. Sturt[13] feels that time is part of our adaptation to our environment; yet men often want to be free from this connection with external objects. One does not have to look far to see how different people adapt differently--in terms of time--to their environment.

Bell and Bell[14] state that human beings have different tempos of living. The tempo of life even varies in an individual during his lifetime. In addition, life tempo varies among the races. It has been demonstrated medically that the average metabolic rate among Orientals is lower than the average rate among Caucasians. Interestingly enough, metabolic rate seems to impose a peculiar tempo upon each individual: some individuals are deliberate, some are leisurely, some are lively and brisk. Each may be equally efficient, but they do live and perform at different tempos.

Introspection confirms what many authors have described regarding the individualistic nature of time. Fraisse[15] has observed that periods in the recent past may seem longer than equal periods in the more distant past. Yesterday may

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[13] Sturt, op. cit., pp. 143-150.

[14] Bell and Bell, op. cit., p. 91.

[15] Fraisse, op. cit., pp. 167-168.

have a longer duration than a day in past years. Frankenhaeuser[16] makes much the same observation, viz., that everyday experience suggests that two time periods of the same objective length can vary considerably. Time generally seems shorter when the periods are filled with interesting, pleasant, or amusing activities than when spent in boredom, anxiety, or discomfort. The more attention given to the passage of time, the longer the period will seem. The less attention given to time, the shorter it will seem. Frankenhaeuser feels the influence of attitude and motivation is so strong that experimental variables of a non-emotional nature may be obscured or distorted.

Axel[17] says that varied and interesting experiences will make time seem short in passing, but this same time will seem long as we look back. On the other hand, time that is empty of experience seems long in passing but short in retrospect. A day full of excitement, with no pause, seems to pass swiftly. On the contrary, a day full of waiting seems an eternity.

Sturt[18] points out that within the limits of human experience there are great differences in the power to

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

[17] Robert Axel, "Estimation of Time," Archives of Psychology, XII (November, 1924), p. 7.

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

apprehend time and to deal with temporal ideas. This ability to judge time may vary with the age of the individual and with the degree of culture of the person concerned. Even the same educated adult may experience time differently on different occasions. A man may adjust to a single time in order to cooperate with others, catch his train, and keep his appointments; theoretically, however, this mutual synchronization does not disprove the possibility of the existence of many individual times, once time is admitted to be subjective and not objective.

If, as it seems to be, time is something that varies according to the situation and according to the individual experiencing a duration, what are those things that affect our experience of time? What measures can be made that will reveal more about the experience of duration?

Purpose of the Study

Taking the view that time is subjective, that it is an individual phenomenon, the researcher set out to study some of the variables that might alter a person's perception of time. Specifically, the study concerns the affects of three different aspects of an auditory stimulus: frequency, loudness, and duration.

At the outset the following questions were asked:

1. Does the frequency of a tone affect a person's ability to reproduce a time interval?
2. Does the loudness of a tone affect a person's ability to reproduce a time interval?

3. Does the duration of a tone affect a person's ability to reproduce a time interval?
4. Is there any interrelationship among these three aspects of an auditory stimulus that might affect the reproduction of the interval?

In an attempt to answer these questions, the following null hypotheses were formulated for testing in this study:

1. There is no significant difference in a subject's ability to reproduce temporal intervals of five different durations: 1 second, 3 seconds, 5 seconds, 7 seconds, and 9 seconds.
2. There is no significant difference in a subject's ability to reproduce temporal intervals of five different frequencies: 250 cycles per second, 500 cps, 1000 cps, 2000 cps, and 4000 cps.
3. There is no significant difference in a subject's ability to reproduce temporal intervals of five different loudnesses: 40 phons, 50 phons, 60 phons, 70 phons, and 80 phons.
4. There is a no significant interaction between duration and frequency in a subject's ability to reproduce temporal intervals.
5. There is no significant interaction between duration and loudness in a subject's ability to reproduce temporal intervals.
6. There is no significant interaction between frequency and loudness in a subject's ability to reproduce temporal intervals.
7. There is no significant interaction among duration, frequency, and loudness in a subject's ability to reproduce temporal intervals.

Importance of the Study

As will be evident in Chapter II, there have been several studies dealing with the experience of duration; however, there have been few studies that deal with the effects of the parameters of an auditory stimulus, i.e., frequency, intensity, and duration, on the interpretation of time. Weber emphasises that "a causal analysis of time perception can be made only through the discovery of those conditions that give rise to variations in our experience of time."[19]

Considerable energy has been expended by speech and hearing scientists in an attempt to discover the nature of our interpretation of frequency and intensity. Mencke[20] suggests that much more research is needed to define duration as an auditory stimulus parameter. A few references to previous research will illuminate the problem.

Effects of intensity upon duration.--Fraisse notes the effects of the intensity of the limiting stimuli in unfilled (i.e., silent) intervals: "In the case of brief durations, the more intense the stimuli (auditory) the shorter the interval seems. . . .The more intense the stimuli the denser they appear to be and hence the intervals seem briefer."[21] In the case of filled intervals, however, the more intense the sound is, the longer it will seem. The effect decreases, however, as the duration increases.[22] An

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[19] Weber, op. cit., pp. 235-236.

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

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

[22] Ibid., pp. 130-134.

effect of intensity was also found by Hirsh, Bilger, and Deatherage.[23] Stimuli were presented in a quiet environment and reproduced in noise; in another instance stimuli were presented in noise and reproduced in quiet. They found that the reproductions were longer for stimuli reproduced in noise. This finding was interpreted as evidence of a relationship between perceived time and the level of auditory stimulation. Wallace and Rabin,[24] in their survey of the literature, cite a study by Oleron in which he concluded that if the intensity of sounds is increased during an interval, the duration would be overestimated.

Effects of pitch upon apparent duration.--In studying unfilled intervals Fraisse[25] found that when sounds setting off the interval are of higher pitch, the interval will appear longer than when limited by sounds of lower pitch. He also noted that as the difference in pitch of the limiting sounds is increased, the longer the interval seems to last. In a study by Triplett[26] it was found that a

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[23] I. J. Hirsh, R. C. Bilger, and B. H. Deatherage, "The Effect of Auditory and Visual Background on Apparent Duration," American Journal of Psychology, LXIX (December, 1956), pp. 561-574.

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

[25] Fraisse, loc. cit.

[26] 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.

sound of high pitch seems longer than a deep sound, but Cohen, Hansel, and Sylvester[27] found the opposite.

Pitch can also be affected by duration. Turnbull[28] found that pitch discrimination was affected by the duration of the sound, the shorter sounds being more difficult to discriminate.

Effects of duration upon apparent duration.--Fraisse[29] states that longer durations of the limiting sounds of empty intervals cause the interval to appear longer. This particular author feels that as the amount of time involved is lessened, the more accurate one is in appreciating time.[30] Fraisse does not say at this point, however, whether he means accuracy in actual time or in the percentage of time. Henry,[31] on the other hand, found that the shorter the duration, the fainter the sound, and the lower the pitch, the poorer the discrimination of duration becomes.

Effects of the content of the interval.--It is evident, then, that some authors have suggested that the type of stimulus present during an interval alters or affects the

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[27]John Cohen, C. E. M. Hansel, and J. D. Sylvester, "Interdependence of Temporal and Auditory Judgments," Nature, CLXXIV (October, 1954), pp. 642-646.

[28]William W. Turnbull, "Pitch Discrimination as a Function of Tonal Duration," Journal of Experimental Psychology, XXXIV (August, 1944), p. 315.

[29]Fraisse, op. cit., p. 131.

[30]Ibid., p. 213.

person'a judgment of that duration. It must be stressed, however, that not all agree that the content of the interval affects the interpretation of time. Fraisse[32] has said that, as a general rule, short durations are overestimated and long ones are underestimated regardless of whether or not the intervals are filled or unfilled. Creelman, another recent investigator, questions whether the type of stimulus used has any bearing upon how a person appreciates time. On the basis of his data[33] he predicts that detection of duration differences will increase with signal voltage only at low signal-to-noise ratios; this dependence of our duration discrimination upon intensity becomes negligible as the signals are brought well above the noise. He takes the stand that "duration discrimination depends on sufficient intensity to mark the time unambiguously; it depends on detectibility but not on loudness."[34]

Time factors in speech and hearing.--The duration of sounds is important, even a necessity, in oral communication.

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[32] Fraisse, op. cit., p. 132.

[33] Carleton Douglas Creelman, "Human Discrimination of Auditory Duration" (Unpublished Ph.D. dissertation, Department of Psychology, University of Michigan, 1960), p. 22.

[34] C. Douglas Creelman, "Human Discrimination of Auditory Duration," Journal Acoustical Society of America, XXXIV (May, 1962), p. 592.

MacDougall,[35] among others, stresses the importance of temporal changes in emphasized words. He points out the fact that accentuation lengthens the sound upon which it falls. Expansions and contractions of duration during speech vary in extent with the intensity of the sounds used. According to Mencke,[36] efficient speech communication depends upon man's ability to discriminate changing auditory signals over time. He feels it is important to investigate human being's responses to changes in the parameters of the auditory stimulus.

Hirsh, Bilger, and Deatherage[37] point to the dependence of auditory perception on patterns generated in time. In addition, they stress that adults who have had normal hearing but lost it make two common complaints. One is, obviously, the loss of communication. The other is the fact that life seems to lose its on-going character.

Since an auditory stimulus must be produced and received in time, the results from a properly planned series of experiments might aid in the development of a test for the ability to perceive duration. Such a test might tell one more about normal and abnormal reception and perception of sounds, including speech sounds.

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

[36]Mencke, loc. cit.

[37]Hirsh, Bilger, and Deatherage, op. cit., p. 561.

It is not within the purview of this study to devise such a test. It is hoped, however, that if differential effects of frequency, loudness, and duration are noted in reference to the duration of stimuli, a future study could be made, the goal of which would be to work toward a specific discriminatory test that might be added to our present battery of speech reception and hearing tests.

Definitions

Several terms are commonly employed in the literature on time and in this paper. These terms and definitions follow:

Time.--In *Webster's Third New International Dictionary* the term *time* is defined as follows: "a period during which something (as an action, process, or condition) exists or continues: an interval comprising a limited and continuous action, condition, or state of being: measured or measurable duration."[38] This is only one of fifteen definitions and their subdivisions. Time, however, is defined differently by those interested in the different aspects of time. Bell and Bell discuss some of the different ways of describing time:

> Psychological time. . .is the time we individually experience. Public time is associated with the regulating and recording of human activities by means of the clock and the calendar. Biological time refers

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[38] *Webster's Third New International Dictionary*, 1961, p. 2394.

> to the rhythms and tempos peculiar to living organisms--both plants and animals. Evolutional time represents a long look into the past: an attempt to construct a timetable for the evolution of the universe, the earth, and life upon the earth. Astronomical time and mathematical time, . . .are recognized as pure dimensions. All these are the "same time." The differences lie in the way in which time is viewed.[39]

Gilliland, Hofeld,and Eckstrand[40] point out that physicists will define time as the measurement of the movement of earth through space. Bell and Bell[41] state that to the physicist and the astronomer time is a quantity--a dimension. The psychologist, according to these same authors, would say that ". . .time represents the order in which we experience events or happenings by means of our senses."[42] Bindra and Waksberg say that "elapsed time refers to temporal durations as measured by standard clocks. . . ."[43]

For the purposes of the present study the term time will be used in the sense of physical time, i.e., measured duration as reproduced by the subjects.

Temporal.--In this paper the term temporal will be used in the adjectival sense "of time."

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[39]Bell and Bell, *op. cit.*, p. 14.

[40]Gilliland, Hofeld,and Eckstrand, *op. cit.*, p. 162.

[41]Bell and Bell, *op. cit.*, p. 12.

[42]*Ibid.*

[43]Dalbir Bindra and Hélène Waksberg, "Methods and Terminology in Studies of Time Estimation," *Psychological Bulletin*, LIII (March, 1956), p. 157.

Duration.--Although the term duration is occasionally used synonymously with the term time, some identifying characteristics may be found in these definitions. Webster's Third New International Dictionary lists two definitions of duration that can be considered: (1)"the quality or state of lasting for a period of time: continuation in time or existence;" (2) "a portion of time which is measurable or during which something exists, lasts, or is in progress."[44] James' definition of duration is this: "The unit of composition of our perception of time is a duration. . . ."[45]

The term duration in this study will refer to segments of time that the subjects are asked to reproduce. In essence, the standard interval will be considered a duration; the reproduced interval will be listed as time.

Protensity. Another term used on occasion to denote a certain aspect of time experience is protensity. Webster defines this term as follows: "the duration of a sensation."[46] Woodrow states that "the duration of which one is aware is sometimes called protensity, in order to distinguish it from physical duration."[47] Bartley says that "the

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[44] Webster's Third New International Dictionary, p. 703.

[45] William James, The Principles of Psychology (New York: Dover Publications, Inc., 1950), p. 609.

[46] Webster's Third New International Dictionary, p. 1823.

[47] Herbert Woodrow, "Time Perception," Handbook of Experimental Psychology, ed. S. S. Stevens (New York: John Wiley and Sons, Inc., 1951), p. 1234.

durational aspect of the experience elicited by a stimulus is sometimes called its protensity, as a term paralleling intensity."[48]

Indifference interval.--Throughout much of the study of time, as will be seen in the next chapter, experimenters have often found that some segments of time seem to be longer than they actually are by physical measurement; others seem to be shorter. In between the times that are overestimated and those that are underestimated is a time that is neither; this, essentially, is the indifference interval. Methods of computing indifference intervals vary from study to study and from one psychophysical method to another. Woodrow[49] discusses some of the different ways of defining indifference intervals.

In this study the indifference interval will be taken as the point at which the ratio of the average difference-time divided by the actual duration is equal to zero. It is the point where overestimation changes to underestimation.

Time-order errors.--Woodrow states that "by time-order error is meant the effect due to the temporal order of

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[48]Howard S. Bartley, Principles of Perception (New York: Harper and Brothers, 1958), p. 72.

[49]Herbert Woodrow, "The Temporal Indifference Interval Determined by the Method of Mean Error," Journal of Experimental Psychology, XVII (April, 1934), pp. 173-175.

presentation of the standard and the variable."[50] Time-order errors do not have quite the same meaning in the different psychophysical methods. For this study, in which the method of reproduction is employed, the term negative error will be used when the reproduction of the stimulus is too short; in this case the stimulus interval is underestimated. The term positive error will be used when the reproduction is too long; in this case the stimulus interval is overestimated.

Organization of the Report

Chapter I has introduced some of the concepts and controversies of time perception. Out of these grew the problem to be studied in this paper, *viz*., the effects of frequency, loudness, and duration upon the reproduction of temporal intervals. Pertinent terms necessary to the study of time were defined and discussed.

Chapter II consists of a comprehensive over-view of the previous literature on time and time perception. To be discussed in this chapter are (1) the theories of time perception, (2) the development of the concept of time, (3) certain problems in time studies, (4) psychophysical methods in the study of time, (5) individual factors in time perception, (6) brain dysfunctions, (7) body functions, (8) the effects

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[50]Woodrow, "Time Perception," *op. cit.*, p. 1225.

of varying conditions, (9) duration in speech, and (10) duration and loudness.

Chapter III concerns itself with the criteria for selection of subjects, with the experimental apparatus, and with the experimental procedures. Included in this chapter will be a discussion of the rationale for the selection of stimuli.

Chapter IV presents the results of the statistical analyses. These results will be discussed in light of the hypotheses set forth in Chapter I. Comparison will be made between the present research and past research in the same vein.

In Chapter V there will be a summary of the present study. Conclusions will be drawn on the basis of the analysis, and recommendations for further research will be made.

CHAPTER II

REVIEW OF BACKGROUND LITERATURE

Many theories have been proposed regarding the perception of time. In an attempt to clarify the many theories, authors have approached the problem in several ways. Some authors have written about time perception from an empirical standpoint; others have studied time experimentally. As might be expected, the results from the research and introspection have led to conflicting reports as to the nature of time perception.

Although not all writers would agree on the meaning of the results of the research, it seems clear from the literature that time perception is not a constant phenomenon; varying the conditions can vary the results. As experimenters varied conditions in different ways, different findings were obtained. Several excellent reviews of the literature on time perception are available. Among the most complete are the following: Fraisse,[51] Triplett,[52]

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

[52] Triplett, op. cit., pp. 201-265.

Gilliland and Humphreys,[53] Woodrow,[54] and Weber.[55] In his book Fraisse[56] traces the historical aspects of time studies and discusses how the study of the nature of time passed from philosophy to psychology. With the advent of the new psychophysical methods in mid-19th century, time research moved into the laboratory. Among some of the first problems studied were the application of Weber's Law, the constant errors, and the effects of the content of the interval. Since then several additional approaches have been employed in time studies.

Theories of Time Perception

Gilliland, Hofeld, and Eckstrand[57] have reviewed many of the theories of time perception. Older theories suggested a "time-sense," including an internal clock mechanism. Psychoanalysts have suggested that time perception is some phase of the self. Other theories that have often been suggested are (1) physiological processes,

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

[54] Woodrow, "Time Perception," op. cit., pp. 1224-1236.

[55] Weber, op. cit., pp. 233-252.

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

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

(2) strain, (3) internal temperature, (4) movement of the body, (5) satiation, (6) brain rhythms, (7) drugs and disease, and (8) individual differences.

Cohen[58] suggests that there are different forms of temperal experience: 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 occurrance of an event; and orientation toward the future. Since each person will probably experience many, if not all, of these forms differently, the point is again made that time perception is an individual matter. Sturt[59] stresses that time perception varies not only from individual to individual but also within the same individual.

What are those things, then, that provide the individual with the ability to perceive time? Although it is sometimes difficult to categorize some of the theories into exclusive divisions, certain features seem to fit together into the following theories:

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.

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[58] Cohen, op. cit., pp. 208-209.

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

4. The amount of change determines the perception of time.

5. Duration has a "unity of organization."

Central nervous system mechanisms.--Many authors have tried to explain the brain mechanism used to judge duration and the difference between two durations. A thorough review of these theories can be found in Fraisse.[60] One explanation commonly found refers to brain traces. James states that ". . .each stimulus leaves some latent activity behind it which only gradually passes away. . . ."[61] While we are responding to a present stimulus, we are still hearing the echo of a preceding stimulus. Certain of these processes seem to fade more rapidly than others, especially under certain conditions. This effect leads to different time judgments.

Frankenhaeuser[62] states that if two sounds are presented successively, the impression made by the second stimulus in the pair will be compared with the sinking or fading trace of the first stimulus. The result of this comparison is that the second of two equal intervals in a pair will be judged as being longer. There are instances, however, when the second of two equal intervals

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

[61] James, op. cit., pp. 634-635.

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

will be judged as being shorter than the first. Frankenhaeuser believes this type of error is typically found when the interval between the two stimuli is short. This shortened interstimulus interval may result in ". . .a temporary decrease in the excitability of the sensory path stimulated."[63]

According to Postman,[64] the physiological process of successive comparison depends upon an electrical gradient in the brain field. Excitation of a peripheral organ disturbs the equilibrium in this brain field and leaves a trace. A second stimulus can thus be compared to the trace of the first. The after-affect of the first stimulus fades with time, i.e., the trace "sinks." Postman states that the longer the time between the first and the second stimulus, the more the trace will sink. This would seem to explain what Frankenhaeuser[65] had mentioned: the longer the interval between the first and second stimulus, the greater the likelihood of having the second stimulus judged as longer.

A second common central nervous system theory hypothesizes that we perceive time by memory images.

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[63] Ibid.

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

[65] Frankenhaeuser, loc. cit.

Experiments by Nichols[66] emphasize that memory images depend upon certain rhythmic habit processes of our nervous system and our bodily organism. The degree of correlation between these memories and their originals depends upon how valid our habit processes are. Nichols admits that he does not know what particular portion of the brain is responsible for memory of these rhythmic habits. He does feel that his experiments demonstrate that when these cells function accurately, our judgments of time are also accurate.

Although the proponents of the memory-trace theory feel they have evidence to support their beliefs, not all authors agree. In fact, Angell[67] discusses the memory-image theory of time perception at some length because he considers that it has had an exceedingly harmful influence on psychological research. Edgell[68] ran experiments searching for the explanation for overestimation and underestimation in the comparison of two stimuli; but in separate experiments designed to find a memory image, she claimed to find nothing that would support the theory.

In a recent study Creelman also searches for explanations of the neurological processes that help us make

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

[67]F. Angell, "Discrimination of Clangs for Different Intervals of Time," American Journal of Psychology, XII (October, 1900), p. 79.

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

comparison time judgments. He suggests that perhaps "a 'counting mechanism,' a simple accumulator, could store neural pulses in reverberatory circuits or, for that matter, store an electrical charge due to a chemical process."[69]

The temporal clock mechanism.--From time to time various authors have tried to explain time perception by attempting to find an internal clock. If such an internal clock existed, there would be a time-sense, just as there are other senses. Fraisse[70] and MacDougall[71] both report on Mach's theory that time is a general sense distinct from the five special senses. Just as the eye is the organ for space perception, the ear is, to Mach, the organ for the sense of time. MacDougall points out, however, that the ear cannot be the sole location for the process of time perception; for estimation of time is not restricted to auditory experience. It is just as possible to judge the duration of a visual stimulus.

Fraisse,[72] in his historical discussion on the study of time, indicates that authors have suggested that

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[69]Creelman, "Human Discrimination of Auditory Duration" (Unpublished Ph.D. dissertation), 47.

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

[71]MacDougall, op. cit., pp. 94-95.

[72]Fraisse, op. cit., p. 161.

the mid-brain is the location of the temporal "clock." It is this region that acts as a clock for the organism; all the main periodic rhythms (hunger, thirst, sleep, and sex needs) depend upon the mid-brain. These periodic vegetative occurances may act as a basis for the experience of time.

If there _is_ a human built-in clock mechanism, Renshaw[73] feels it is not accurate. He trained subjects in production and discrimination of unfilled intervals of one and five seconds. Their errors showed that as a human clock, they ran slow by 0.2 per cent.

Today few authors adhere to the belief in a special "time-sense;" nevertheless, we often hear the term _time-sense_ used. What is meant by this term, according to Bartley,[74] is that time is something experienced or that the human can relate himself to clock time. Although Bartley feels we cannot make time perception the function of a specific body sense, he does feel the body is active in a clock-time continuum: "It may be that the very nature of certain body processes, including the activities of several sensory mechanisms, is responsible for the experience of time and the ability of the organism to

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[73]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.

[74]Bartley, _op. cit._, p. 69.

relate itself to the clock. Just what these mechanisms and processes are is not yet known."[75]

<u>Bodily rhythms</u>.--Several bodily processes have been mentioned in the literature in regard to the perception of time. Fraisse[76] points out that studies have shown that animals have some ability to estimate duration. These estimates, of course, are not based on any symbolic representations nor on intellectual processes. This leads Fraisse to believe that man, too, is probably capable of estimating duration on a biological level. He suggests that it is a combination of biological promptings and constructions of the mind that allows us to make judgments with surprising accuracy. In his review of this theory Fraisse[77] reminds us that Wundt felt that introspective sensations could come from the ears and from feelings of tension and relaxation. These would give us temporal signs through which we could order them in time.

In his argument against a special time-sense, MacDougall[78] has said that subjective standards of measurement are dependent upon physiological changes. To

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[75] <u>Ibid</u>., pp. 69-70.

[76] Fraisse, <u>op. cit</u>., pp. 62-63.

[77] <u>Ibid</u>., p. 80.

[78] MacDougall, <u>op. cit</u>., pp. 92-93.

MacDougall both the forms of aesthetic apprehension and the sense of time itself depend upon the phases rhythmical motor impulses. When two intervals are to be compared, a person will reproduce them through a motor process. To him, variations in the tension of the sense organs form the basis for the judgment of short durations. The rhythms of respiration determine our estimates of longer durations.

As might be expected, there are some who do not accept the theory of bodily rhythms as an explanation for the ability to estimate time. Nichols[79] mentions that breathing, pulse-beat, and leg swing have all been suggested as aiding in the estimation of time. Nichols has pointed out in his objections that there is no reason why one unconscious process should dominate as a standard more than another. In a series of experiments, Woodrow[80] asked his subjects what methods they used to estimate time. He felt that these introspections did not support the notion that estimation of long intervals is an estimation of a rhythmical nature. Although the subjects' reports did mention noticing breathing and series of thoughts, the subjects did not have the feeling that there was an unconscious counting involved. Renshaw[81] found that his

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

[80]Herbert Woodrow, "The Reproduction of Temperal Intervals," Journal of Experimental Psychology, XII (December, 1930), p. 494.

[81]Renshaw, loc. cit.

experimental results did not fit the theory of time perception based on kinesthetic cues. He found that subjects who tapped with their hands or feet, counted, or made any phasic movement made poorer judgments than those who remained still and alert.

Amount of change.--Some investigators believe that the appreciation of duration is based upon change. According to Bartley,[82] this concept of change applies both to external stimuli and to body processes. These changes then serve as a cue for estimating time. Sturt[83] has stressed that although we cannot perceive time directly as we can taste, smell, or touch, we can perceive that things change.

Fraisse[84] feels there is a relationship between physiological changes and behavior. Under the influence of these periodic changes, the organism becomes a physiological clock that provides cues for temporal orientation both in animals and man. This same author feels there is a relationship between these periodic changes and the movement of the universe. Nature is set off by the tides, the alteration of night and day, the lunar cycle, and the seasons. Living organisms have rhythmic changes of the

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[82]Bartley, op. cit., p. 72.

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

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

pulse, the respiratory cycle, digestion, sleep, menstruation, migrations, etc. Working on the premise that duration consists of nothing other than successive changes, Fraisse has proposed the following "laws:" "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."[85]

James feels that even though we try to empty our mind of any means of comparing time, some form of changing process--such as heart beats, breathing, pulses of attention, fragments of words or sentences--remains for us to feel.[86] In general, James feels that, in retrospect, "many objects, events, changes, many subdivisions, immediately widen the view as we look back. Emptiness, monotony, familiarity, make it shrivel up."[87]

The concept of unity.--For Boring,[88] duration cannot be an immediate experience since certain physiological events must exist prior to reporting the experience. He argues that if the term immediate experience means without lapse of time, it cannot be applied to time. He suggests, instead, substituting the term continuity for immediacy.

[85] Ibid., pp. 218-219.

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

[87] Ibid., p. 624.

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

If the perception of time is a matter of continuity, how much time must elapse before one event has ceased and another event has begun? Sturt[89] suggests that there appears to be an intuitive duration that man can apprehend as a whole. Fraisse[90] believes in the existence of a perceived present, that duration that can be apprehended as a unit. The limit of the present is, according to Fraisse, approximately five seconds. Far more often our present is limited to only two or three seconds. This particular author feels, then, that an event lasting more than five seconds is not a unified event but rather the beginning of a series of events.

James[91] cites research that indicates the spacious present may be anywhere in a range from 3.6 to 12 seconds. Reference is made by Woodrow[92] to the temporal span of attention, that time over which stimuli may be spread and yet perceived as present. He suggests that there is both a maximal and a minimal threshold for this span of attention. Kowalski[93] determined from introspective reports that a time interval must reach a duration of more than 1.5 seconds in

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

[90]Fraisse, op. cit., pp. 84-93.

[91]James, op. cit., pp. 612-613.

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

[93]Walter J. Kowalski, "The Effect of Delay upon the Duplication of Short Temperal Intervals," Journal of Experimental Psychology, XXXIII (September,1943), p. 239.

order to have a definite experience of duration. In his review of the concept of unity Woodrow[94] believes the upper limit of the psychological present is about six seconds. Summarizing several investigations, Woodrow concludes that the range of unity probably lies between 2.3 and 12.0 seconds.

Development of the Concept of Time

Bell and Bell[95] feel that primitive man became aware of time by the rhytmical changes in nature and in himself. Man then discovered time could be divided into three parts: present, past and future. Fraisse feels that "the birth of the notion of time is no doubt the result of the experience of successions, of which some are periodic and others not, of continuous and discontinuous change, of interwoven renewals and relatively permanent states."[96]

In attempting to trace some of the developments that took place leading toward a time concept, Sturt[97] lists three primitive time experiences: (1) the

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

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

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

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

apprehension of an event as having duration in time; (2) the apprehension that an event has occurred before, or will occur after, another; and (3) the experience of two things occurring simultaneously. Conventional time units, the history of the world, and the abstraction of time are time experiences of late construction.

Several investigators have attempted to show the development of the time concept in children. Although Fraisse[98] found that children and adults have exactly the same feeling that the time of waiting is too long and that the time of effort is never-ending, Sturt[99] indicates that children have considerable difficulty learning these measures of time. Fraisse[100] has provided a chronology of the understanding and use of terms designating a precise location in time:

Recognize a special day of the week	4 years
Tell whether it is morning or afternoon	5
Use words yesterday and tomorrow correctly	5
Indicate the day of the week	6
Indicate the month	7
Indicate the season	7-8
Indicate the year	8
Indicate the day of the month	8-9
Estimate the duration of a conversation	12
Estimate the duration "since the holidays"	12
Give the time to within 20 minutes	12

[98] Fraisse, op. cit., p. 238.

[99] Sturt, op. cit., p. 85.

[100] Fraisse, op. cit., p. 180.

Fraisse notes that children first become oriented to the rhythm of everyday experiences. Subsequently they learn to organize time into sequence. Training appears to be important in the appreciation of duration, for this author[101] has found that training children to estimate duration improves this ability.

Studying the development of time sense in children, Oakden and Sturt[102] showed that the growth of the sense of time was slow. The sense of time seemed to start around four years and to reach adult level around 13 or 14 years. The most important period for rapid growth of the sense of time was 11 years of age. Children first learn the meaning of time words in ordinary use, and their early concepts seem to be closely related to activities or concrete experiences. Arranging dates or historical characters in time was difficult for children.

Children, ages 18 months to eight years, were asked questions about time by Ames.[103] She noted that learning of this concept goes from specific to general, e.g., the children can name some or all of the months before they understand the concept of the word month. She also found

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[101] Ibid., p. 238.

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

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

marked individual differences that do not seem to be related to intelligence. Ames found that the learning of certain time concepts took place at these ages.

Tell their age	3 years
Morning-afternoon	4
When their next birthday is	4
What day it is	5
Days of the week named	5
When they go to bed	5
How old they will be next birthday	5
When they have supper, get up, go to school	6
What time it is	7
What month, season	7
What year	8
What day of the month	8
Months of the year named	8

Springer[104] studied four to six year old children with no school instruction in their knowledge of the clock and in their ability to tell time. They were asked to tell time and to tell about their daily activities and about the clock. From the study, Springer felt the sequence of development was as follows: (1) able to tell time of regularly occurring activities, (2) able to tell time by a clock, (3) able to set the clock, and (4) able to explain why the clock has two hands and how each works.

In a study of the nature and development of the concept of time in children, kindergarten through third grade, Harrison[105] used fifty commonly used terms selected

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[104]Doris Springer, "Development in Young Children of an Understanding of Time and the Clock," Journal of Genetic Psychology, LXXX (March, 1952), pp. 83-96.

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

from vocabulary studies. The data gathered in the investigation indicate that the development of time concepts is correlated with grade development. Harrison feels that the development of language plays a large role in the development of the time concept.

Smythe and Goldstone[106] studied time perception in children ages six to fourteen by asking them to estimate short durations. A 725 cycle tone was presented in steps of 0.1 second from 0.1 to 2.0 seconds. The subjects were asked whether the tonal duration was more or less than one second. These authors concluded that there was a tendency for all age groups to overestimate the value of one second. It was found, however, that the variability of the one-second estimates decreased with age. Children of six and seven did not improve in their estimates, but subjective judgments of a second by children eight through fourteen and adults <u>did</u> improve with information. Smythe and Goldstone concluded that children begin to make estimates like adults around the age of 14.

Problems in the Study of Time Perception

In the research on time perception certain psychophysical problems exist. Among those problems receiving

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[106]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. 49-59.

considerable attention are the following: (1) Weber's Law, (2) the time-order error, (3) indifference intervals, and (4) methods used in judging.

Weber's law.--Henry[107] has compiled a fine review of the literature as it relates to Weber's Law and temporal experience. Weber's Law can be stated by the formula $\frac{\Delta S}{S} = C$. ΔS is a differential increase in a stimulus, S, that can produce a just-noticeable-difference, or j.n.d. In essence. Weber's Law states that the incremental ratio of the j.n.d. is a constant, C, over the entire range of the stimulus.

Many authors have tried to determine whether Weber's Law holds for time perception. Fraisse[108] reminds us that Fechner tried to apply Weber's Law to time but found varying results; Nichols[109] came to the conclusion in 1890 that Weber's Law could not be applied to temporal intervals. Edgell,[110] Mencke,[111] and Small and Campbell[112] are also among those who have found that duration does not obey Weber's Law.

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[107]Henry, op. cit., pp. 734-743.

[108]Fraisse, op. cit., p. 141.

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

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

[111]Mencke, loc. cit.

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

Gilliland,[113] on the other hand, found that Weber's Law seemed to be verified for a duration range of 4-27 seconds. Henry noted there was a sharp increase in the Weber ratio at the shortest times used (32 and 47 milliseconds); beyond these times there was a ". . .slight tendency for the Weber ratio to decrease more or less linearly with increased duration over the stimulus range studied."[114] In a second experiment Henry found that varying the stimulus intensity had little effect upon the results except for a tendency for a somewhat higher Weber ratio for the lowest intensity used (20 dB). The result confirmed the trend found in the first experiment: there is a smaller ratio at the longer duration. In another experiment he held duration and intensity constant and varied frequency. Henry found a tendency for the Weber ratio to be highest for low frequencies.[115] Creelman[116] found that Weber's Law did hold approximately for duration discrimination but only in some very special experimental circumstances.

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

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

[115] Ibid., p. 739.

[116] Creelman, "Human Discrimination of Auditory Duration," Journal Acoustical Society of America, p. 592.

As can be seen from the preceding paragraphs, Woodrow is close to the truth when he says that "on the whole, the data are rather indecisive as to whether a Weber's Law relationship holds for intervals beyond 4 sec. or not. They do establish, however, that there is on the average very little change in the relative variability beyond 4 sec."[117]

The time-order error.--Frankenhaeuser describes the concept of the time-order error in psychophysics as follows: "The difference between subjective and objective equality induced by the order of presentation is designated the time-order error. 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. Time-order errors occur in both directions, positive and negative, but the negative errors are by far the most common."[118]

Woodrow[119] states that when two intervals are compared, a negative error exists when the second of two

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[117]Woodrow, "The Reproduction of Temporal Intervals," p. 493.

[118]Frankenhaeuser, loc. cit.

[119]Leo Postman, "The Time-Error in Auditory Perception," American Journal of Psychology, LIX (January, 1946), p. 193.

equal intervals is judged to be longer (the first, therefore, is conceived to be underestimated). A positive error results when the second is judged shorter (first therefore overestimated). When the intervals are reproduced, errors are called negative when the reproduction is too short (stimulus interval is conceived as underestimated) and positive when the reproductions are too long (stimulus interval conceived as overestimated).

In discussing the effects of the time interval between the two stimuli in a pair, Kreezer[120] says that as the time interval between the two stimuli increases, the size of the negative time-error tends to increase. When the interval between the two items of a pair decreases, there is a tendency for the second stimulus to be reported as less intense than the first. This would result in a positive time-error. Postman[121] also indicates that the size of the interval between the two items of a pair will affect the judgments of overestimation or underestimation; however, he reports that time-erros are related to the particular experimental conditions in which the comparison judgments are made. Needham[122] states that with an interval

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

[121]Leo Postman, "The Time-Error in Auditory Perception," American Journal of Psychology, LIX (January, 1946), p. 193.

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

of approximately three seconds, the time-error is small or absent. When the interval between the two stimuli is between 3-12 seconds, the time-error becomes increasingly negative. When the interval is brief--from 0-3 second-- the error is positive.

The indifference interval.--An excellent review of of the literature on the indifference interval can be found in Woodrow.[123] It was Vierordt who first stated as a law that short intervals are overestimated and long ones underestimated. This law carries the implication that there are some intervals that are neither over-estimated nor underestimated; this intermediate length is called the indifference interval.[124] To state it another way, the point where the time-order error is zero is the indifference interval.

Woodrow[125] disagrees with the conclusion that seems to be generally held regarding the indifference point, *viz*., there is a human tendency to overestimate short intervals and to underestimate longer ones. He

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

[124]Woodrow, "Time Perception," p. 1225.

[125]Woodrow, "The Reproduction of Temporal Intervals," pp. 473-474.

believes that intervals are estimated only relative to each other; any constant error made is simply an error due to the order of presentation. A short interval may be underestimated if it is the second of a pair but overestimated if it is the first of the pair. Irrespective of temporal order, a short interval is neither overestimated nor underestimated.

Since the average error of estimation is zero at the indifference point, Doehring[126] feels that time estimation is most accurate at this point. He reports some experiments have found no indifference point, whereas others have found a reversal of the usual trend from overestimation to underestimation. Stevens[127] reported an indifference interval between .53 and .87 second; but where previous investigators had found that there was a tendency for subjects to subtract from long intervals and add to short ones, he concluded just the opposite.

James[128] reports that from many studies it seems that the interval of 3.4 of a second is the interval of time most easy to catch and reproduce. Great variation

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[126] D. G. Doehring, "Accuracy and Consistency of Time-Estimation by Four Methods of Reproduction," American Journal of Psychology, LXXIV (March, 1961), p. 34.

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

[128] James, op. cit., pp. 617-618.

in the findings for the indifference interval is reported by Woodrow.[129] Findings have ranged from .36 to 5.0 seconds, but indifference intervals of 0.5 to 0.7 second have been reported more frequently than others.

Many authors have looked for an explanation for the variety of findings. Stott[130] concluded, from a series of experiments, that the experience of the subjects played a part in the discrepancies. Clausen[131] found that with the method of verbal estimation, all intervals used were overestimated. With the methods of operant estimation and reproduction he found that shorter intervals have a tendency to be overestimated and longer ones underestimated. Frankenhaeuser[132] feels that contextual factors influence the results of experiments dealing with the indifference interval. She states that the point of the indifference interval varies with the range of stimuli used; it tends to lie in the middle of the stimulus series employed.

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

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

[131]Johs Clausen, "An Evaluation of Experimental Methods of Time Judgment," _Journal of Experimental Psychology_, XL (December, 1950), p. 760.

[132]Frankenhaeuser, _op. cit._, p. 21.

Woodrow[133] also reports that in a long experiment the indifference interval tends to move towards the average length of the intervals constituting the whole series. The development of a central tendency is one of the most important conditions affecting the indifference interval, according to Fraisse.[134] When we prepare to make a judgment of some experience, we judge it against what we expect it to be, i.e., the average. The result is that as subjects compare to the average, they overestimate those durations that are below the average and underestimate those above it. The divergence in findings, Fraisse feels, is a result of the different ranges used by different investigators; the value of the indifference zone is modified according to the range of durations used in an experiment.

Woodrow[135] feels some of the disagreement comes from the use of different psychophysical methods. He does not feel the indifference interval by the method of reproduction should be regarded as the same thing as the indifference interval by the method of comparison. This same author reports investigations that have shown the opposite of Vierordt's Law; "it follows that, even under

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[133]Woodrow, "Time Perception," p. 1227.

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

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

fixed experimental conditions, there is no single indifference interval valid for all subjects."[136]

Methods used in judging.--Another problem that is present in the study of time is the way in which the subjects are asked--or allowed--to estimate time. The fact that not all experimenters give the same instructions to their judges could, and probably would, lead to differing results. Axel[137] allowed his subjects to use any means of estimation except a watch. He then asked the subjects to report what methods they used. They reported the following methods:

1. Counted 60 to a minute
2. Imagined a second hand moving
3. Counted on the style of a clock ticking
4. By a swaying movement
5. Listening to the heart beat
6. Regular movements of the foot
7. Just guessed
8. Made allowance for difficulty of the work
9. By the amount of enery expended
10. The quality of their work
11. On the basis of mental strain
12. Compared time with previous tests.

Nichols,[138] who served as his own subject, reported that his best judgments were made by paying attention to the norm during the sample beats of a metronome; then, when the rhythm was "caught," he tried to get himself as

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[136] Woodrow, "Time Perception," P. 1226.

[137] Axel, op. cit., pp. 45-46.

[138] Nichols, op. cit., p. 83.

unconscious as possible, letting the idea or habit of the rhythm run its own course undisturbed. The subjects used by Alvord and Searle[139] gave introspective testimony that revealed the following methods of time judgment: (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. These authors found great individual differences in the methods used. Where the method of strain and relaxation were used, there was a tendency for the subjects to shorten the longer intervals.

In two studies Woodrow[140,141] discusses at length some of the methods subjects used to reproduce durations. He found that when subjects reproduce intervals in an automatic manner, paying no attention to their finger movements, the reproductions were relatively short. When the subjects were instructed to reproduce intervals by thinking and concentrating on their movements, the reproductions were much too long.

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[139]Edith A. Alvord and Helen E. Searle, "A Study in the Comparison of Time Intervals," American Journal of Psychology, XVIII (April, 1907), pp. 177-182.

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

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

Gilliland[142] first allowed his subjects to use any method of estimation; on a second trial they were asked not to count. When subjects were left to their own methods, he found that they invariably resort to some form of counting. Gilliland reports that judgments can be almost as accurate without counting. Accuracy, however, is dependent upon how much attention is paid to the interval. If subjects give only casual attention and do not count, they have no adequate cues for judgment. Under these circumstances subjects made errors that averaged one-half larger than when they counted. Practice by counting reduced the errors from 25-30 per cent to 5 or 10 per cent; practice without counting did not improve the scores.

Although Gilliland believes that the motor rhythm of counting problems cues for time estimation, MacDougall[143] feels that motor movements tend to interfere with the estimation of time intervals. He found that estimations were most accurate when the subjects listen passively. When motor activity is introduced, the ability to make exact comparisons is interferred with.

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[142] Gilliland, *op. cit.*, pp. 243-255.

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

Psychophysical Methods in the Study of Time

In both preceding and following sections it will be noted that several psychophysical methods have been used in time studies. A brief description of the most common methods and samples of each will be presented. Two have been employed more frequently in recent research--reproduction and comparison; these will be discussed last in greater detail.

The method of estimation.--In this method the subject is given a temporal interval--either filled or unfilled--and is asked to estimate verbally how long he thought the interval lasted. Clausen[144] calls this the method of verbal estimation.

In a study using this method Sturt[145] asked the subject to estimate in seconds or minutes the time that a pencil was held in the air. Sturt found considerable irregularity both in accuracy and in the comparative length of the real and apparent time. In this study there was no constant tendency to judge time as either too long or too short. It was also noted that practice did not improve the ability to estimate time.

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[144] Clausen, *op. cit.*, p. 756.

[145] Sturt, *op. cit.*, pp. 93-94.

Urban[146] reports a study in which it was found that subjects using the method of estimation tended to use some numbers more than others. The numerals _0_ and _5_ were used most; those numerals next to _0_ and _5_ were used least. In another study mentioned by Urban it was found that low numbers tended to be used more than high numbers. Axel[147] also found that there was a tendency for certain final digits to appear more than others. He found that the final digit _0_ occurred in 42.5% of the judgments; the final digit _5_ appeared in 29.0%. All other digits combined were found in only 28.6% of the judgments. Even numbers comprised 61.1% of the judgments; 38.9% were odd numbers.

The method of production.--In this method the subject is asked to produce a signal--or a silent interval--of a stated duration given by the experimenter. Clausen[148] calls this the method operative estimation, to distinguish it from the method of verbal estimation. In this particular method the term _overestimation_ means that the subject "allows less chronological time to elapse before he considers the stated value as having been reached. Thus,

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[146] F. M. Urban, "On Systematic Errors in Time Estimation," _American Journal of Psychology_, XVIII (April, 1907), pp. 187-188.

[147] Axel, _op. cit._, pp. 20-22.

[148] Clausen, _loc. cit._

the smaller the elapsed time i.e., the time produced, the greater the overestimation."[149] In one of her studies Sturt[150] asked the subjects to start a stop watch and then stop it after a certain number of seconds had passed. She found, as she did in the method of estimation, that there was no definite tendence to judge time as either too long or too short. Falk and Bindra[151] asked subjects to produce a temporal interval of 15 seconds. They found that both the experimental group and the control group had overestimations in the early trials and underestimations in the late trials.

The method of fractionation.--In the method of fractionation a subject is presented with an interval and is then asked to produce another interval that is half as long as the standard presented. This method has been used to construct psychological scales for various functions. The following terms for these scales have been suggested: veg for weight, gust for taste, sone for loudness, and mel for pitch.

Ross and Katchmar[152] set out to construct a similar scale for the perception of short time intervals. The

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[149] John L. Falk and Dalbir Binda, "Judgment of Time as a Function of Serial Position and Stress," Journal of Experimental Psychology, XLVII (April, 1954), p. 279.

[150] Sturt, op. cit., p. 93.

[151] Falk and Bindra, op. cit., pp. 279-282.

[152] Sherman Ross and Leon Katchmar, "The Construction of Magnitude Function for Short Time-Intervals," American Journal of Psychology, XLIV (July, 1951), pp. 397-401.

psychological term coined by Ross and Katchmar was the chron. One chron was arbitrarily chosen as that time experienced by the subject when he is presented with a clocked interval of ten seconds. It was found that the standard deviations were small with this method of judgment. The half-judgments were fairly accurate between five and thirty seconds.

A scale of half-time was also constructed by Gregg,[153] only he called his unit temps. One temp was arbitrarily selected as equivalent to one second. The duration which was found to be one-half of one second was 505 milliseconds; this time was given the value of .5 temp. Gregg found that subjects were quite accurate in judging halftime.

Fraisse questions the construction of such a scale for time by stating that ". . .there is little to be gained from subjective time scales since, allowing for difficulties connected with the method, the apparent half of another apparent duration is equal to the true half of the latter."[154]

The methods of comparison.--Two psychophysical methods of comparison have often been employed in the judgment of time: the constant method and the method of limits. In the constant method a standard stimulus and a variable stimulus (one of selected equal-steps above and

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

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

below the standard) are presented as a pair. The pairs are presented in an irregular order, and the variable stimulus usually both precedes and follows the standard. The subject judges whether the second item of the pair is more than, equal to, or less than the first.

In the method of limits a standard stimulus and the variable stimuli are chosen in the same way as in the constant method. In this case, however, the standard stimulus is generally presented first and the variable stimuli are presented in an ascending or a descending series. The subject judges whether the variable is more than, equal to, or less than the standard.

In an experiment employing the constant method Creelman[155] held the standard time constant and varied the difference time. The results showed that detection of differences became easier as the difference between the standard and the variable became larger. In a second experiment Creelman used five different standards and kept a constant difference time (0.1 second) between the standard and the variable. It was found that as the standard time is increased, detection of a difference between the standard and the variable decreases. In a third experiment Creelman found that greater signal voltage resulted in better detection of a difference and

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[155] Creelman, "Human Discrimination of Auditory Duration" (Unpublished Ph.D. Dissertation), p. 26.

greater duration resulted in poorer detection. Creelman concluded that duration discrimination depends on the detectability of the signals, because there may be an uncertainty as to the starting time when the signal level is low. When the signal level is loud enough to be easily detected, the effect of signal level on duration discrimination becomes negligible.

Using the method of constant stimuli, Shaefor[156] had subjects listen to pairs of randomly arranged continuous, warbled, and pulsed tones. In this study subjects required a duration difference of at least .28 second in order to detect a difference in warbled tone, a duration of .48 second for continuous tones, and .51 second for pulsed signals. The face that the pulsed signals apparently interferred with judging duration differences would seem to discredit the theory that some form of rhythmic stimuli aids in judging duration. Shaefor found that her subjects had greater difficulty in discriminating short tones than long tones. In addition, she found a positive time-error--the second of the two intervals tended to be judged as shorter. She attributes this finding to the fact that her stimuli were not counterbalanced; the standard was always presented first.

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[156] Patricia Shaefor, "A Study of the Perception of Duration of Continuous, Warbled, and Pulsed Signals" (Unpublished Master's thesis, Michigan State University, Department of Speech, 1963), pp. 32-33.

In a study employing the method of limits Small and Campbell[157] used four standard durations, seven variable durations around each standard, four different interstimulus intervals (the duration between the standard and the variable), and three frequency levels. All stimuli were presented at 50 phons. These authors found that the ratio $\frac{\Delta T}{T}$ increased markedly as duration was shortened, i.e., discrimination deteriorated. The size of the interstimulus interval had more effect as the duration was shortened; as the interstimulus interval was shortened, discrimination became poorer, but interstimulus interval lost its effect as duration was lengthened.

Mencke[158] investigated the ability of normal hearing subjects to discriminate small changes in durations. Three frequencies (250 cycles per second, 1000 cps, and 4000 cps), two sensation levels (10 dB and 50 dB), and four reference durations (40 milliseconds, 60 msec., 80 msec., and 100 msec.) were employed. It was found that subjects differed in their ability to discriminate changes in signal duration. It was concluded that the magnitude of the difference limen for short auditory stimulus duration depends on the stimulus frequency and intensity and on the duration of the reference stimulus. Short stimulus duration

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[157] Small and Campbell, _op. cit._, pp. 401-410.

[158] Mencke, _loc. cit._

difference limen resembled the difference limen at low frequencies and intensities. Milburn[159] used the same frequencies and sensation levels as Mencke but lengthened the durations to 300, 500, and 1000 milliseconds. He concluded that the magnitude of the relative difference limen of pure-tone auditory stimuli is related to duration of the reference stimulus and to sensation level but is not highly dependent upon the stimulus frequency.

The method of reproduction.--Although variations exist, the usual method of employing this procedure is to present the subject with a given interval of time, either a silent interval or an interval filled with some stimulus. The subject is asked to reproduce this temporal interval.

Spencer[160] studied reproduction in this manner: the experimenter gave a sharp rap on the table with a ruler setting off four intervals (of 15, 30, 60, and 100 seconds); the subject reproduced the intervals by starting and stopping a stop watch. Spencer noted that in the course of the experiment, subjects occasionally lost track of the interval or became distracted so that certain responses

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

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

were abnormally shortened or prolonged. (Such reactions might be expected when the concept of "unity" is considered.)

Edgell[161] found the individual subject's favored interval for reproduction. Intervals above and below the favored interval were then presented. It was found that periods that were longer than the favored interval were underestimated; those shorter than the favored period were overestimated.

In one of his studies Woodrow[162] presented empty intervals bounded by two impact sounds. Each subject heard intervals ranging from 0.2 to 30.0 seconds and reproduced each fifty times by tapping on a key twice--once to begin the interval and once to end it. The subjects were told not to count and not to make any movements of a rhythmical nature. They were to avoid paying attention to breathing. In his summary Woodrow stressed that the errors found revealed the following:

1. There was no universal tendency for long intervals to be underestimated or for short ones to be overestimated.
2. Some subjects underestimated short intervals and overestimated long ones. Some did the reverse; some overestimated all intervals.
3. Subjects sometimes overestimated an interval one day and underestimated it the next.
4. A difference in attitude of the subjects could bring about a reversal in the sign of the errors.

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

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

He found that the variability was smaller for shorter intervals than for longer ones. There was, on the average, very little change in the relative standard deviations for intervals of six seconds and beyond; there was a marked increase in variability between 1.5 and 4-6 seconds.

In a similar experiment Woodrow[163] used the same method but used a range of intervals from 300 to 4000 milliseconds. By having different groups of subjects reproduce each interval, he overcame the problem of central tendency. When reproducing the shortest interval, 84% of the subjects made reproductions that were too long; 73% of the subjects showed negative errors when reproducing the longest interval. The change from a positive to a negative error occurred between 600 and 700 milliseconds. The value obtained by interpolation for the indifference interval was 625.3 milliseconds.

Hirsh, Bilger, and Deatherage[164] asked subjects to reproduce the duration of a stimulus, either a tone or a light, that was presented to them. Ambient conditions of light or dark and quiet or noise were controlled by the experimenter. Four combinations of ambient conditions were possible: light and quiet, light and noise, dark and quiet, and dark and noise. These authors found that

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

[164]Hirsh, Bilger, and Deatherage, op. cit., pp. 561-574.

the duration of 1, 2, and 4 seconds were, on the average, overestimated. The longest duration of 16 seconds was underestimated. The duration of eight seconds, one-half of the range, would be what has traditionally been called the indifference interval. When the conditions remained the same during both the stimulus interval and the response interval, no difference was found between responses made under conditions of quiet and those of noise nor any difference between responses made in light and those in dark.

Later the experimenters varied the conditions from stimulus to response. In this analysis they found that responses made in noise to a tone or light presented in quiet seemed longer than a response made in quiet to stimuli presented in noise. As they changed the visual conditions from dark to light or from light to dark, the results were not significantly different from those obtained under the control conditions. They concluded from this that changes in the acoustic background effect changes in the apparent duration of stimuli, whereas changes in the visual background do not.

With this finding as a hypothesis they presented different loudness levels between the original quiet condition of 30 dB and the original noise condition of 90 dB. These data showed again that the duration of a response in noise following stimulation in quiet is greater than the duration of a response in quiet following stimulation in noise. As the difference between the noise levels decreased, the differences in the responses decreased. These authors summarize by saying that since the apparent duration seems to depend upon the level of auditory stimulation and not upon the level of visual ambient stimulation, there is probably a strong relationship between psychological time and the level of auditory stimulation.

Kowalski[165] controlled the period of time between the end of the stimulus and the beginning of the subject's response and found that it was the stimulus durations and not the delay intervals that were the significant factors in the overestimation or underestimation of time reproductions. As the stimulus duration increased, the per cent of estimation decreased. There was a slight but insignificant tendency for estimations to become more accurate with the increase in the length of the delay intervals. (These findings would not support the theory that memory traces supply us with a means of judging time; for if that were so, the longer the delay intervals, the less accurate would be the judgments.)

As might be expected, these different psychophysical methods do not produce the same results. Fraisse[166] has

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[165]Kowalski, op. cit., pp. 239-246.

[166]Fraisse, op. cit., p. 212.

stated that studies have shown that there is little, if any, correlation among the methods. Although Woodrow believes that results from the different methods cannot be compared, he feels that "the greatest accuracy for both discrimination and reproduction lies between the range extending from 0.2 to 2.0 seconds."[167]

According to Fraisse[168] the error is less by the method of reproduction than by that of production; both methods give smaller errors than the method of estimation. The variability from one subject to another and also within one subject is greatest by the method of estimation. This particular author feels that the reproduction method is the most reliable, but its disadvantage is that it only permits the experimenter to consider short durations. Kowalski[169] agrees that the method of reproduction is more accurate and flexible than the other methods.

Clausen[170] studied three methods of judging time: verbal estimation, operative estimation, and reproduction. He found that the method of verbal estimation resulted in marked overestimation. The methods of reproduction and

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[167] Woodrow, "Time Perception," p. 1225.

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

[169] Kowalski, op. cit., p. 239.

[170] Clausen, op. cit., pp. 756-761.

operative estimation resulted in underestimation for 10- and 15-second intervals and overestimation for a 5-second interval. Accuracy was less by verbal estimation, but there were high correlations among the subtests.

In his discussion of the comparison of these three psychophysical methods Clausen states that the method of reproduction involves a different underlying function than do verbal and operative estimation. Although the method of reproduction produces average judgments that are closer to the stimulus interval than is the case in either of the other two methods, this method shows more instability than the other two methods. For this reason Clausen prefers both verbal estimation and operative estimation over the method of reproduction. Of these two, Clausen prefers the method of operative estimation. In contrast, Hawkes, Bailey, and Warm[171] found no differences among the same three methods. Of interest in this matter is the fact that Clausen used schizophrenic subjects, whereas Hawkes, Bailey, and Warm used normal subjects.

Obviously, the findings of Fraisse and Kowalski, who found that the method of reproduction was reliable, do not

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[171]Glen R. Hawkes, Robert W. Bailey, and Joel S. Warm, "Method and Modality in Judgments of Brief Stimulus Duration," Journal of Auditory Research, I (January, 1961), p. 142.

coincide with the findings of Clausen. Neither of these two contradictory findings agrees with Hawkes, Bailey, and Warm. Several explanations for these different findings are possible, among them their methodologies, their instructions, the fillings of the intervals, and the different lengths of the intervals used. It could very well be, however, that the subjects used--in the case of Clausen's study, schizophrenics--affected the results obtained.

Individual Differences

Fraisse[172] points out that there have been few studies in which the authors did not find marked individual differences. He feels that the importance of the attitude of the subjects in the perception of time must be recognized. He proceeds to say that our perceptions are not only a function of the nature of the stimuli but also of the assumptions with which we apprehend them. Our perceptions depend upon previous experience, upon the context of perception, and upon our personality. Such statements cause Fraisse to conclude that ". . .control over time is essentially an individual achievement conditioned by everything which determines personality; age,

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[172] Fraisse, *op. cit.*, p. 145.

environment, temperament, experience. . . . Time is a conquest strongly marked by the personality of the individual."[173]

Woodrow[174] has concluded that whether reproductions of an interval will be overestimated or underestimated depends upon the subject. In two studies[175,176] Woodrow kept all of the external conditions constant and found that the variations between subjects were due to variation in the ways in which they went about their task. Wallace and Rabin[177] feel that certain individual differences in the awareness and judgment of time are due to certain developmental and experiment al events in the organism. Such a relationship, however, between temporal experience and personality factors has not yet been clearly demonstrated.

Motivation and attitude.--Woodrow[178] mentions two attitudes that can be taken in estimating time: in the objective attitude the subject concentrates upon the characteristics of the stimulus; in the subjective attitude

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[173] *Ibid.*, p. 177.

[174] Woodrow, "The Reproduction of Temporal Intervals," p. 490.

[175] Woodrow, "Individual Differences in the Reproduction of Temporal Intervals," p. 275.

[176] Woodrow, "The Temporal Indifference Interval Determined by the Method of Mean Error," p. 172.

[177] Wallace and Rabin, *op. cit.*, pp. 231-232.

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

attention is centered upon the experience of duration only. In a study dealing with the difference between these two attitudes, Woodrow found that giving maximal attention to the second of two tones caused an overestimation of its duration. When subjects listened passively to the second tone, they underestimated its duration.

Fraisse[179] feels that when there is little motivation, a subject attends to the various steps of the task; he is easily distracted by outside incidents or by chance thoughts and may concentrate on the effort involved. When a subject is strongly motivated, however, he becomes absorbed in the task itself. Under these circumstances the subjects are not aware of the passing of time.

By altering the amount of subject motivation through controlling the rate of progress toward and the distance from a goal, Meade[180] found that the nearer the goal, the lower the estimate of time and that the faster the progress, the lower the estimate of time. In a second study on motivational factors Meade[181] used longer time intervals but found approximately the same results as in the earlier experiment: in the low motivational groups, time

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[179]Fraisse, op. cit., p. 220.

[180]Robert D. Meade, "Time Estimates as Affected by Motivational Level, Goal Distance, and Rate of Progress," Journal of Experimental Psychology, LVIII (October, 1959), pp. 275-279.

[181]Robert D. Meade, "Effect of Motivation and Progress on the Estimation of Longer Time Intervals," Journal of Experimental Psychology, LXV (June, 1949), pp. 327-331.

estimates were not affected by the rate of progress. In the high motivational groups, estimates were shorter under rapid progress than they were for slow progress.

Filer and Meals[182] gave three groups the task of writing words by using alternate letters of the alphabet for ten minutes. The subjects were actually stopped after four minutes and 37 seconds and asked to estimate the time they had been working. Two experimental groups were given rewards for doing the task; a control group was given no reward. The results showed that the subjects who were motivated to complete a task believed that they had worked longer at the task than individuals not so motivated. The authors concluded that persons who are motivated to have time pass quickly will estimate a given duration to be longer than will persons who are not motivated to have time pass quickly.

Nichols[183] found that nervousness and excitement shortened time judgments. Those items coming first in an experiment tended to be shorter than later ones when practice had occurred. Hindle[184] gave subjects different kinds of

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[182]Ronald J. Filer and Donald W. Meals, "The Effect of Motivating Conditions on the Estimation of Time," Journal of Experimental Psychology, XXXIX (June, 1949), pp. 327-331.

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

[184]Helen Morris Hindle, "Time Estimates as a Function of Distance Traveled and Relative Clarity of a Goal," Journal of Personality, XIX (September, 1950-June, 1915), pp. 483-501.

psychological test material and set it up in such a way that she could control the clearness of the goal and the scores made. She came to the conclusion that in the early part of an activity, estimates of time increase with increments in the score made. In the latter part of an activity, time estimates increase more slowly when there is a clearly defined goal.

In a study dealing with success and failure in time estimation, Harton[185] found that for 29 of his 32 subjects, time seemed less at successful activity than at failure. In another study Harton[186] asked some subjects to estimate how long it took them to complete a long maze, a task representing "unity of organization." Another group completed several short mazes. He found that time seemed less when one goal was striven for and attained than when many goals were striven for and attained.

Rosenzweig and Koht[187] asked whether there might not be a significant relationship between the presence of a tension in the mind and the manner in which elapsed time

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[185] John J. Harton, "An Investigation of the Influence of Success and Failure on the Estimation of Time," *Journal of General Psychology*, XXI (July, 1939), pp. 51-62.

[186] 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.

[187] Saul Rosenzweig and Aase Grude Koht, "The Experience of Durations Affected by Need-Tension," *Journal of Experimental Psychology*, XVI (December, 1933), pp. 745-774.

is estimated. Subjects were given unsolvable puzzles and asked to estimate the time the experimenter was out of the room. They found that

> . . . duration is subjectively long when we want it to be short and short when we want it to be long. When we want time to be short, we are often very attentive to its passing as is especially apparent in case time is empty or unpleasantly filled. When, on the other hand, we want time to be long, we are ordinarily attending to what is occupying us, and in this case time is probably filled and moreover, pleasantly or with the anticipation of pleasure.[188]

According to Sturt[189], time estimates depend on attention. If this attention is destroyed, we become oblivious to the passage of time. The more attention paid to time, the longer the period will seem. Fraisse[190] also suggests that the more attention that a person pays to time, the more likely an interval will be overestimated. Of all the attitudes a person may take, the one which seems to have the greatest amount of influence in estimating time is attention.

<u>Anxiety</u>.--Falk and Bindra[191] gave their experimental subjects a shock from a galvanic skin response unit; a control group received no shock. In the anxiety-producing situation--shock from the GSR--the subjects had significantly greater overestimation of time than a comparatively neutral

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[188]*Ibid.*, p. 773.

[189]Sturt, *op. cit.*, pp. 89-92.

[190]Fraisse, *op. cit.*, pp. 146-147.

[191]Falk and Bindra, *op. cit.*, pp. [illegible].

situation. The authors concluded that this greater overestimation of the interval by the experimental group was due to an anxious set induced by the expectation of shock. Frankenhaeuser[192] gave her subjects a mild shock and required them to estimate time intervals following the shock. The shock did not seem to result in anxiety, but but the anticipation of the shock apparently made the time seem long. She felt that this increase in apparent time was caused by the condition of sustained attention rather than anxiety.

Students of Henrikson[193] had mentioned in a speech class that time seemed long when they were speaking, especially if they were afraid. These subjects were asked to estimate a period of time in which they were doing nothing. Each then gave an impromptu speech, after which he estimated his speaking time. It was found that subjects judged the non-active period as longer than it actually was and judged the speaking period as shorter than it actually was. Although differences were not significant, those students who felt little stage fright tended to overestimate their speaking time, whereas those with great stage fright tended to underestimate time.

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[192]Frankenhaeuser, op. cit., pp. 85-86.

[193]Ernest H. Henrikson, "A Study of Stage Fright and the Judgment of Speaking Time," Journal of Applied Psychology, XXXII (October, 1948), pp. 532-536.

Subjects of Langer, Wapner, and Werner[194] judged a specific time interval while moving toward and away from a precipitous edge. Blindfolded subjects were asked to indicate an interval of five seconds by pressing and releasing a button; this operated the moving platform as well as the timer. It was found that time was increasingly overestimated as danger increased.

Practice effects.--James has stated that "like other senses, too, our sense of time is sharpened by practice."[195] Saetveit, Lewis, and Seashore[196] state that achievement in all measures on the Seashore Measures of Musical Talent are subject to improvement with training. Rhythm and memory seem to be more subject to such improvement than the four elemental measures of pitch, loudness, time, and timbre. Research with the Seashore tests has shown that this improvement with practice is often a result of a change in work method, not in actual spontaneous hearing. The work method is often influenced by attitude, division of labor, tendency to anticipate, and lazy or indifferent

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[194] Jonas Langer, Seymour Wapner, and Heinz Werner, "The Effect of Danger upon the Experience of Time," American Journal of Psychology, LXXIV (March, 1961), pp. 94-97.

[195] James, op. cit., p. 618.

[196] Joseph G. Saetveit, Don Lewis, and Carl E. Seashore, "Revision of the Seashore Measures of Musical Talents," University of Iowa Series on Aims and Progress of Research, No. 65 (October, 1940), p. 40.

resort to guessing. In a study by Triplett[197] a "musical" group had less variability in the estimation of duration than those subjects who were "non-musical." Such findings suggest that practice does improve the "sense of time."

Stott[198] found that previous experience in comparing durations was an important factor in determining the time-order errors and the indifference interval. In this study it was found that with naive, unpracticed subjects the time-order indifference point for tonal duration was approximately 0.92 second. For subjects who served throughout the series, the indifference duration was between 1.6 and 2.0 seconds. The only practice effect found by Woodrow and Stott[199] was an upward gravitation of short durations toward both the series average and a previously determined 900 millisecond indifference interval. Standard intervals and intervals longer than the standard were found to gravitate upward toward the indifference duration as much after practice as in the initial trials.

In a study using the method of estimation, Gilliland[200] found that practice by counting reduced scores from 25-30%

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[197]Triplett, _op. cit._, pp. 260-263.

[198]Stott, _op. cit._, pp. 741-746.

[199]Herbert Woodrow and Island H. Stott, "The Effect of Practice on Positive Time-Order Errors," _Journal of Experimental Psychology_, XIX (December, 1936), pp. 694-705.

[200]Gilliland, _op. cit._, p. 255.

errors to 5-10% errors. Practice without counting had no effect on improvement. In a study by Sturt[201] there was no sign of improvement through practice.

Age differences.--Fraisse[202] points out that for the child the future plays a larger part than the past in his consciousness. In the adult, however, age causes a decline in the importance of what is yet to come and more importance is placed on what has already taken place. Fraisse feels that man attaches the greater importance to the longer portion of his life. The young put more emphasis on the unlived portion of life, the elderly on what they have already experienced.

This same author also feels that there may also be a change in biological time as we grow older. It has been noted that wounds take longer to heal in the aging individual. The number of biological changes which take place in the young cause the organism to work more. The more changes that take place and the more work accomplished result in an apparent increase in time. Time thus seems longer to the young than to the old.[203] Frankenhaeuser[204]

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[201]Mary Sturt, "Experiments on the Estimation of Duration," British Journal of Psychology, XIII (April, 1923), p. 383.

[202]Fraisse, op. cit., pp. 181-182.

[203]Ibid., pp. 246-247.

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

also feels that this apparent acceleration of time with age can be explained in terms of change. Youth is filled with many events; but as the years pass, experience becomes more automatic, and the days and weeks smooth themselves out.

Fraisse[205] believes that the ability to estimate time develops slowly until approximately 16 years of age. If the reproduction method is used, however, children seem to appreciate duration at a fairly early age. Since children do not have the ability to use actual time measurements in their verbal estimates of duration, they are more dependent than adults on what takes place during the interval.

Improvement in time estimation between nine and eleven years was found by Axel[206]; beyond eleven years of age, improvement proved to be negligible. In estimating the length of a 40-second interval the nine year olds and the 14 years olds were equally accurate, but the nine year olds tended to overestimate the interval, whereas the 14 year olds tended to underestimate the interval. Axel found that elementary school boys tended to overestimate duration more than did college men; in addition, the college students were more accurate and less variable.

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[205]Fraisse, _op. cit._, p. 236.

[206]Axel, _op. cit._, pp. 52-66.

Gilliland and Humphreys[207] found that adults were superior to fifth grade children in judging the length of short intervals of time; however, the fact that children were as successful as they were, caused Gilliland and Humphreys to report that children had already developed certain cues for time estimation. Counting proved to be an important aid for both children and adults. The reproduction method seemed to be the easiest method for judging time.

Goldstone, Boardman, and Lhamon[208] asked children to count off thirty seconds in two different ways: to themselves and out loud. It was found that of the two methods, counting aloud resulted in longer estimates. These authors found that it was difficult for six and seven year old children to count to themselves. Some form of kinesthetic help (by tapping or moving their lips) seemed necessary for them to express their temporal concept. They found estimates of a second were quite accurate by the eight year old through adult groups. Estimates by six and seven year olds and by older adult groups were significantly shorter.

Sex differences.--In a study by Yerkes and Urban[209] it was found that the length of a second is slightly

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[207]Gilliland and Humphreys, op. cit., pp. 129-130.

[208]Sanford Goldstone, William K. Boardman, and William T. Lhamon, "Kinesthetic Cues in the Development of Time Concepts," Journal of Genetic Psychology, XCIII (December, 1958), pp. 185-190.

[209]Robert 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.

overestimated by males and greatly overestimated by females. The intervals from 18 to 108 seconds were generally underestimated slightly by men but greatly overestimated by women. They also found that the estimates made by women were more variable and less accurate than the estimates made by men. Both men and women tended to favor estimates ending in _0_ and _5_ as well as simple fractions of a minute, but this tendency was greater among women. Axel[210] came to the conclusion that there is a strong tendency for males to underestimate durations of time ranging from 15 to 30 seconds. In the case of females, however, marked overestimations appear for these intervals. MacDougall[211] found that when men were allowed to estimate in any way possible, they underestimated, whereas women overestimated. He concluded that, in general, women show greater inaccuracy, consistant overestimation, and greater variability than man. Gulliksen[212] also found that women tended to estimate duration as being longer than men.

In a study where subjects estimated time by counting and by not counting, Gilliland[213] found little difference

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[210] Axel, _op. cit._, pp. 30-31.

[211] Robert MacDougall, "Sex Differences in the Sense of Time," _Science_, XIX (April, 1904), pp. 707-708.

[212] Harold Gulliksen, "The Influence of Occupation upon the Perception of Time," _Journal of Experimental Psychology_, X (February, 1927), pp. 52-59.

[213] Gilliland, _op. cit._, p. 254.

in time estimation between men and women. Although early studies showed some sex differences in time judgment, Gilliland, Hofeld, and Eckstrand[214] did not find these differences. One explanation suggested by these authors is that modern women are called upon to estimate time as often as men; hence, with the importance of time increasing in modern woman's life, she becomes practiced in time estimation.

Brain Dysfunctions

Mental disturbance.--Fraisse[215] feels that the normal attitude of man is oriented toward the future. Even when man is oriented toward the present, it requires an attention to time, to reality. Refuge into the past and escape from time altogether are attitudes that refuse to face reality. In describing some cases of temporal disorientation among the mentally disturbed, Fraisse says that since asthenics desire nothing, they cannot suffer from frustration, especially temporal frustration.

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[214] Gilliland, Hofeld, and Eckstrand, op. cit., p. 178.

[215] Fraisse, op. cit., p. 198.

According to Lewis[216], time is essential to all reality; it is essential to all conscious activity. Not only do gross disorders of time estimation occur in organic psychoses, but they can also occur in the functional psychoses. In his work Lewis reviews the ways in which time is normally perceived and follows this with an application to the mental disorders. Israeli[217] describes some of the time distortions found in a variety of mental disorders. He uses case histories to illustrate his points then suggests methods of dealing with these time distortions clinically.

Schilder[218] also reviews some of the literature and gives case histories illuminating how time can be distorted for the mentally disturbed. He reports that mental patients have complained that they cannot orient themselves in time. Some patients feel far removed from their previous life; one patient said that the word _time_ had lost its sense. Other patients experience the present as though it were past.

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[216]Aubrey Lewis, "The Experience of Time in Mental Disorder," _Proceedings of the Royal Society of Medicine_, XXV (November-April, 1932), pp. 611-620.

[217]Nathan Israeli, _Abnormal Personality and Time_ (New York: Nathan Israeli, 1936), pp. 1-123.

[218]Paul Schilder, "Psychopathology of Time," _Journal of Nervous and Mental Disease_, LXXXIII (May, 1936), pp. 530-546.

Although the mentally ill may be temporarily disoriented regarding conventional time, Fraisse[219] found that they are not disoriented as to the hour of the day. He does suggest, however, that a mentally disturbed patient cannot perceive a long series of sounds as well as a normal adult.[220]

Comparing schizophrenic patients with normal college students, Weinstein, Goldstone, and Boardman[221] found that schizophrenic patients were more likely to overestimate the duration of a clock second than were normal controls. (Overestimation of the duration of the clock second in this case means that subjects think a second has actually passed before the clock second has taken place.) The explanation of this overestimation by schizophrenics that the authors offer is that there is a slowing down of worldly time for these people; when fantasy activity dominates behavior, external events appear slower by comparison.

Lhamon and Goldstone[222] found that both autistic schizophrenics and normals overestimated the duration of

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219Fraisse, op. cit., p. 41.

220Ibid., p. 95.

221Alvin D. Weinstein, Sanford Goldstone, and William K. Boardman, "The Effect of Recent and Remote Frames of Reference on Temporal Judgments of Schizophrenic Patients," Journal of Abnormal and Social Psychology, LVII (1958), pp. 241,244.

222William T. Lhamon and Sanford Goldstone, "The Time Sense," A. M. A. Archives of Neurology and Psychiatry, LXXVI (December, 1956), pp. 625-629.

one clock second, i. e., the subjects said the second had passed before it actually had by clock time. Although both groups overestimated, Lhamon and Goldstone conclude that the schizophrenic patient is likely to overestimate to a greater degree.

Rabin[223] asked schizophrenic subjects to estimate how much time had elapsed during psychological testing. The results showed that the non-psychotics had a consistently narrower range of estimation than did the psychotic subjects. The majority of the schizophrenics made poor judgments, especially for the longer periods of time.

<u>Mental deficiency</u>.--According to Fraisse, " . . . the temporal horizon of mental defectives, like that of young children, is very limited. Both are incapable of assembling their memories to form a past (and of anticipating a future); they are prisoners of the present."[224] Fraisse cites a study that showed that the temporal horizon of some extreme cases of mental deficiency did not exceed about ten days.

Gothberg[225] compared the development of time understanding between normals and mentally defectives by asking

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[223]A. I. Rabin, "Time Estimation of Schizophrenics and Nonpsychotics," Journal of Clinical Psychology, XIII (January, 1957), pp. 88-90.

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

[225]Laura C. Gothberg, "The Mentally Defective Child's Understanding of Time," American Journal of Mental Deficiency, LIII (1949), pp. 441-445.

her subjects questions regarding time. She found a high correlation between the questions answered and mental age. It was not until the mental age of five was reached that 50 per cent of the children responded to time concepts. Concepts of sequence, historical time, measurement of duration, and chronology were most difficult for the mentally deficient. These concepts did not appear to mature until after the mental age of ten and were beyond the capacity of the majority of the mental age of twelve.

Brain damage.--Fraisse[226] points out that one of the fundamental disorders of aphasia is the disturbance in the perception of rhythm. According to Fraisse, disturbance of spatial and temporal forms are often found in agnosia. Experiments have shown that persons with brain damage often have difficulty in perceiving apparent motion, a condition which is a form of integration of successive information. This author explains that this may be due to the fact that integration in brain damaged cases takes longer.

Body Functions

Physiological Activity.--Schaefer and Gilliland[227] measured pulse rate, heart work, breathing rate, breathing

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[226]Fraisse, op. cit., pp. 96-97.

[227]Vernon G. Schaefer and A. R. Gilliland, "The Relation of Time Estimation to Certain Physiological Changes," Journal of Experimental Psychology, XXIII (November, 1938), pp. 545-552.

rate, breathing work, and blood pressure changes while their subjects estimated unfilled intervals. The subjects were then given vigorous exercises that were followed by another series of estimations. All the physiological processes varied greatly throughout the experiment, but what changes there were in individual estimations of time did not show any constant or definite relationship to these changes in physiological condition. In addition, they found there was no significant difference in the errors whether the subject was in a state of rest or whether he was in a state of great physiological activity.

Strain and muscular activity.--Bartley[228] mentions that there are two common reports of kinesthetic experience in time estimation: passive waiting or awareness of strain. This feeling of strain may arise from almost anybody muscles; sometimes it may involve the arms and legs; at other times it may involve muscles of breathing and the vocal organs. In some cases the subjects have reported they tried to imagine singing or humming to estimate time.

In attempting to determine the method used for time comparison, MacDougall[229] found that "strain intensities" have played a great part. Strain sensations seem to come

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[228]Bartley, op. cit., p. 71.

[229]MacDougall, "Rhythm, Time and Number," pp. 95-96.

from the expectant attitude of the whole body. MacDougall feels that the more intense the strain, the longer the interval will seem; the less the strain, the less it will seem.

Woodrow[230] also feels that some sort of strain is the most common cue advanced as the basis for judgments of duration. To appreciate duration of an interval, an act of attention is required. This act produces strain, either as a central process or through the muscular tensions. It is generally held that the feeling of strain increases with the duration of attention. In one study Woodrow[231] introduced muscular activity by asking his subjects to reproduce both the interval and the bounding clicks and found that in this particular case muscular activity--the tapping of a key--actually hindered the judgments of temporal duration.

Sense modalities.--Sturt[232] believes that different people respond to time differently. Some people may visualize time, whereas others, the audiles, may represent time as notes of varying duration. She even feels that some people have a time scheme represented by motor imagery.

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[230]Woodrow, "Time Perception," p. 1235.

[231]Herbert Woodrow, "Behavior with Respect to Short Temporal Stimulus Forms," Journal of Experimental Psychology, XI (August, 1928), pp. 261-262.

[232]Sturt, The Psychology of Time, pp. 139-140.

Fraisse[233] believes that the duration of a visual sensation and an auditory sensation cannot be directly compared. The organs of smell, taste, and sight have considerable inertia; therefore, it is more difficult for these senses to recognize change. The organs of hearing and touch, on the other hand, have practically no inertia. Touch, however, can only give information concerning changes that take place in contact with the body. As a result, it is through hearing that we perceive and appreciate change, time, succession, rhythm, and tempo. Hearing is the "time sense" just as sight is the space sense.

The time needed to identify that a continuous light is present takes approximately 0.12 second, whereas the duration thresholds for continuous sound vary from 0.01 to 0.05 second.[234] Cohen[235] states that we are able to discriminate auditory time better than visual time. Two auditory stimuli are sensed as being separate at an interval of 2 milliseconds; for visual stimuli, however, it takes 50 milliseconds.

Using the Seashore Measures of Musical Talent, Gridley[236] presented paired sounds to the ear and

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[233] Fraisse, op. cit., pp. 81-83.

[234] Woodrow, "Time Perception," pp. 1230-1231.

[235] Cohen, op. cit., p. 210.

[236] Pearl Farwell Gridley, "The Discrimination of Short Intervals of Time by Fingertip and by Ear," American Journal of Psychology, XLIV (January, 1932), pp. 18-43.

vibrations to the thumb of her subjects. It was found that subjects were more accurate in the discrimination of short intervals of time by ear than through the finger tip.

Gault and Goodfellow[237] studied two types of behavior, discrimination and reproduction, in response to auditory, visual, and tactual stimuli. It was found that the mean score in discrimination was higher for audition; vision was second and tactual last. With the reproduction method the sense of audition again resulted in the highest scores; touch was second.

Subjects of Goldstone, Boardman, and Lhamon[238] were asked to judge whether a tone (or light) was more or less than one second. The variable stimuli were presented in a series of .10 second steps around one second. The results showed that a visual second was considerably longer than the auditory second. When simultaneous stimuli were presented to both senses, it was found that stimulus intensity affected the judgments. When the visual stimulus was more intense than the auditory stimulus, judgments closely approximated the visual-alone responses; when the auditory

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[237]Robert H. Gault and Louis D. Goodfellow, "An Empirical Comparison of Audition, Vision, and Touch in the Discrimination of Temporal Patterns and Ability to Reproduce Them," Journal of General Psychology, XVIII (1938), pp. 41-47.

[238]Sanford Goldstone, William K. Boardman, and William T. Lhamon, "Intersensory Comparisons of Temporal Judgments," Journal of Experimental Psychology, LVII (April, 1959), pp. 243-248.

stimulus was more intense, judgments approximated the auditory-alone responses.

Goodfellow[239] compared audition, vision, and touch in time discrimination by three different psychophysical methods. All three methods gave the same results: audition showed the greatest sensitivity and the least variability; the opposite was true of vision. On the other hand, Hawkes, Bailey, and Warm[240] found that auditory judgments did not differ from visual or cutaneous judgments. The latter two, however, were significantly different. Judgments based on cutaneous cues were greater than judgments based on visual cues.

Pain.--Sturt[241] had a subject hold a lighted cigarette against her hand as long as the experimenter held up a pencil. The subject was then asked to estimate the amount of time involved. It was found that estimates of time were more accurate in this experiment than in other experiments where pain was not involved. In a similar experiment performed at a later date, however, it was found that the experience of pain led to the greatest amount of errors.

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[239] Louis D. Goodfellow, "An Empirical Comparison of Audition, Vision and Touch in the Discrimination of Short Intervals of Time," American Journal of Psychology, XLVI (April, 1934), pp. 243-258.

[240] Hawkes, Bailey, and Warm, op. cit., pp. 139-143.

[241] Sturt, "Experiments on the Estimates of Duration," p. 383.

Temperature.--Using diathermy, Hoagland[242] controlled body temperatures. The subject was asked to count as temperature was varied, and it was found that with an increased temperature there was an increase in the speed of counting. Hoagland concluded that psychological time seems to depend upon certain chemical processes. The author takes his findings to mean that there must exist a master chemical clock.

Vaso-motor waves.--Stevens[243] had subjects reproduce empty intervals of 7.24 seconds as a finger plethysmograph recorded their vaso-motor waves. A relationship was found between vaso-motor waves and the fluctuation in the judgment of an interval of time. In intervals of medium length (0.4 to 2.0 seconds) vaso-motor changes predominated; for longer intervals (3.7 to 7.24 seconds) respiration was of greater influence.

Thyroid activity.--Gardner[244] felt that since the thyroid gland influences the rhythms of circulation and

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[242]Hudson Hoagland, "The Physiological Control of Judgments of Duration: Evidence for a Chemical Clock," Journal of General Psychology, IX (1933), pp. 267-287.

[243]H. C. Stevens, "The Relation of the Fluctuations of Judgments in the Estimation of Time Intervals to Vaso-Motor Waves," American Journal of Psychology, XIII (January, 1902), pp. 1-27.

[244]W. A. Gardner, "Influence of the Thyroid Gland on the Consciousness of Time," American Journal of Psychology, XLVII (October, 1935), pp. 698-701.

metabolism, changes in thyroid activity would be paralled by variations in time perception. Patients in various stages from normal thyroid activity to hyperthyroid activity were asked to estimate verbally a 45 second interval between two strikes of a bell. Later, they were also asked to produce a one minute interval. Subjects tended to overestimate time in the verbal estimation test and to underestimate time in the production test. It was found that in the hyperthyroid group there was a lengthening of the subjective minute. It had been felt that, with the physiological clock going faster in these hyperthyroid cases, time might be estimated as shorter than normal. When the hyperactive thyroid had been removed, there was a resultant 25% drop in the estimates by production. He concluded, however, that there is no correlation in either the active or passive tests between estimation of time and age, pulse rate, or basal metabolism, or with the effects of surgery. ". . .the evidence at hand is against the view that bodily rhythms of pulse or metabolism as influenced by the thyroid gland form a basis of the temporal time judgments."[245]

Sleep and hypnosis.--It has been pointed out by Fraisse[246] that people have temporal orientation during

[245] Ibid., p. 701.

[246] Fraisse, op. cit., pp. 43-46.

sleep. People have some idea of what time it is when awakened by an unusual noise or by a nightmare. In addition, it has been found that people can wake up at certain predetermined hours. It is easier to do this when the desired hour of awaking is near the usual time of awaking; nevertheless, it has also been shown that such estimates are possible at other times. Fraisse feels this can be explained by some sort of physiological clock that gives the sleeper internal cues.

When attempting to awaken at a specified hour, Brush[247] varied the time of arising and the duration of sleep. He found he could estimate the time of awaking with considerable accuracy. The average actual time of awaking was closer to the preplanned time than to a time one might have expected for awaking by habit. General physical condition, the amount and character of sleep, the mental activity subsequent to setting up the time, the illumination in the room on awaking, and the motivation all were important in this matter.

Fraisse[248] tells us that if hypnotized subjects are told during hypnosis that they are going to awaken in a half-hour, they can do this accurately. On the other hand, if they are told they are going to take a long walk for

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[247]Edward N. Brush, "Observations on the Temporal Judgments During Sleep," American Journal of Psychology, XLII (July, 1930), pp. 408-411.

[248]Fraisse, op. cit., pp. 231-232.

a half an hour and are then awakened after ten minutes, the subjects will likely estimate the duration of their "walk" as a half an hour. If a task is suggested, a subject's estimation upon awakening will be very close to the amount of time it would generally take to perform the task.

Drugs.--Fraisse[249] has found that drugs accelerating the vital functions lead to the overestimation of time, whereas those that slow them down lead to underestimation. This particular author also has pointed out that in cases of intoxication with the drugs hashish or mescaline, time seems very long. Goldstone, Boardman, and Lhamon[250] tested subjects under three conditions: pre-drug, 30 minutes post-drug, and 60 minutes post-drug. They found that the drug dextro-amphetamine caused a significant decrease in the clock-measured value of the apparent second. Quinal barbitone and placebo resulted in an increase in the clock-measured value of the apparent second. The increase or decrease found was greater in the 60 minute post-drug condition than in the 30 minute post-drug condition.

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[249] Ibid., pp. 228-229.

[250] Sanford Goldstone, William K. Boardman, and William T. Lhamon, "Effect of Quinal Barbitone, Dextro-Amphetamine, and Placebo on Apparent Time," British Journal of Psychology, XLIX (November, 1958), pp. 324-328.

Frankenhaeuser[251] administered a sedative (phenobarbital) to decrease alertness and a stimulant (metaphetamine) to increase alertness. She found that time estimations were smaller after the intake of the depressant than after the intake of the stimulant. Her explanation of this phenomenon was that the amount of mental content decreases with the depressant. This same author[252] found that quinine did not produce any reliable changes in time estimation. The results did show, however, that objective seconds were subjectively longer under the influence of caffeine.

It is known that the drug lysergic acid diathylamide. (LSD) can produce schizophrenic-like behavior. Boardman, Goldstone, and Lhamon[253] gave LSD to four male subjects and asked them to indicate whether durations were less or more than one second. It was found that the subjects' estimations of a second did not become smaller as in a previous study with schizophrenics. Although no schizophrenic-like estimations were found, variations did increase, a finding suggesting that the subjects' temporal frames of reference did become vague.

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[251]Frakenhaeuser, op. cit., pp. 66-67.

[252]Ibid., pp. 96-103.

[253]William K. Boardman, Sanford Goldstone, and William T. Lhamon, "Effects of Lysergic Acid Diethylamide (LSD) on the Time Sense of Normal," A. M. A. Archives of Neurology and Psychiatry, LXXVIII (September, 1958), pp. 321-324.

Effects Of Varying Conditions

Anchors and serial position.--James[254] has pointed out that the sense of time, like the other senses, is subject to the law of contrast. An interval will sound shorter if a long interval has immediately preceded it. Fraisse[255] feels that such an "anchor" effect must also be taken into consideration in the study of time. Essentially an anchor is a reference value; if subjects are given a particular reference, their future estimates or judgments of duration may be affected.

It is the contention of Goldstone, Lhamon, and Boardman[256] that subjects select a few stimuli--probably the end ones--from a presented series and use these as standards for judgment. They experimented with a very short anchor (0.1 second), a long anchor (2.0 seconds), and a neutral anchor (1.0 second), the last being equal to the standard interval to be judged. The authors found that although subjects tended to overestimate the value of the clock second under all three conditions, short anchors tended to pull the judgments down and long anchors tended to pull the judgments up.

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[254]James, loc. cit.

[255]Fraisse, op. cit., pp. 120-121.

[256]Sanford Goldstone, William T. Lhamon, and William K. Boardman, "The Time Sense: Anchor Effects and Apparent Duration," Journal of Psychology, XLIV (July, 1957), pp. 145-153.

Eson and Kafka[257] had subjects produce two time intervals, 15 seconds and two minutes. The purpose of this study was to determine whether or not the position in the series--early or late--had any effect on the time estimates. These authors found that nearly all subjects overestimated the rate of the passage of time in this task. (Overestimation in this case means that the production is shorter than the interval given by the experimenter.) It was found that the later judgments were not overestimated as much as early judgments. They discovered that the first estimate did seem to establish a reference--an anchor--for the later judgments.

Limiting stimuli.--Woodrow noted that varying the length of the bounding stimuli affected the comparison of time intervals. When he presented a long bounding click, then the interval and a short click, he found there was an overestimation of the interval. When a short click-interval-long click sequence was used, the interval was underestimated. He suggested that lengthening both the terminal sound and the initial sound--individually or together--caused the interval to be judged longer. Making the initial sound longer had a greater effect than

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[257]Morris E. Eson and John S. Kafka, "Diagnostic Implications of a Study in Time Perception," Journal of General Psychology, XLVI (April, 1952), pp. 169-183.

making the terminal sound longer. Woodrow's explanation is that it is more difficult to ignore the initial sound than the terminal sound.[258] In a similar study using the method of reproduction Woodrow[259] found the same trend: whenever a long limiting sound is given, it has the effect of lengthening the interval to be judged; this is more true when the long interval is in the initial position.

Type of activity.--In her studies Sturt found that ". . .in estimating time we rely on the amount of mental content experienced during that time. Time which has been filled by many thoughts appears longer, whereas time occupied by few thoughts appears shorter."[260] Fraisse[261] feels that the more interesting a task is, the shorter it will seem. This latter author has also suggested that the less activities are broken up the shorter the duration will seem. The more unity a task has, the more interesting it will be; this, too, leads to a feeling of shorter duration. Difficult tasks also seem shorter.

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[258] Herbert Woodrow, "Behavior with Respect to Short Temporal Stimulus Forms," Journal of Experimental Psychology, XI (June, 1928), pp. 167-193.

[259] Woodrow, "Behavior with Respect to Short Temporal Stimulus-Forms," (August, 1928), pp. 259-280.

[260] Sturt, "Experiments on the Estimates of Duration," p. 387.

[261] Fraisse, op. cit., pp. 223-225.

By having subjects learn one long maze and several short mazes, Harton[262] found that when a task involves only one goal, time seems shorter than when the task involves several goals. This same author[263] asked subjects to count the slow and fast beats of a metronome. He found that time passed more quickly at the fast rate for his subjects. In a second part, subjects said nonsense verse to beats of the metronome. He found that when the activity was more difficult, subjects judged time as being shorter. To Harton it seemed evident that it was not the rate of beats of the metronome but the <u>activity</u> of the individual that determined the judgments of time.

Gulliksen[264] presented periods filled with eight different types of activity and found that the way in which the individual is occupied or employed causes differences in estimations of time. Complete rest was judged as the longest time, whereas doing long division was judged as the shortest time.

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[262]John J. Harton, "Time Estimation in Relation to Goal Organization and Difficulty of Tasks," <u>Journal of General Psychology</u>, XXVII (July, 1942), pp. 63-69.

[263]John J. Harton, "The Influence of the Difficulty of Activity on the Estimation of Time," <u>Journal of Experimental Psychology</u>, XXIII (September, 1938), pp. 270-287.

[264]Gulliksen, <u>loc. cit.</u>

Subjects of Postman[265] were given three different tasks at each experimental session: adding, crossing out letters, and filling missing letters. The order of presentation was changed from session to session. Afterward the subjects were asked to estimate how much time had elapsed. Postman found that his subjects overestimated the length of the middle task more than the lengths of the first and last tasks. Neither type of task nor the length of the interval caused any significant differences in estimates.

DeWolfe and Duncan[266] asked subjects to reproduce a standard interval of 26 seconds. The authors reasoned that if a subject did nothing during the standard interval, it would make the interval seem long; if they performed a difficult task during the reproduction interval, it would make the interval seem short. DeWolfe and Duncan found that the higher the level of behavior of the standard task, the shorter were the estimates; the higher the level of the comparison task, the longer were the estimates.

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[265]Leo Postman, "Estimates of Time During a Series of Tasks," American Journal of Psychology, LVII (July, 1944), pp. 421-424.

[266]Ruthanne K. S. DeWolfe and Carl P. Duncan, "Time Estimation as a Function of Level of Behavior of Successive Tasks," Journal of Experimental Psychology, LVII (August, 1959), pp. 153-158.

The preferred finger-tapping rate for individual subjects was found by Denner, et al.[267] The subjects were then asked to reproduce an interval of time by three different tapping rates: slower than the preferred rate, at the preferred rate, and faster than the preferred rate. They found that when the tapping rate was faster than preferred, there was an apparent shortening of the physical interval; when the tapping rate was slower than preferred, there was an apparent lengthening. They concluded that with a change in tempo there was a subsequent change in apparent duration.

Loehlin[268] had subjects estimate the duration of a two-minute interval after being occupied with different tasks. The four main variables that contributed to the apparent length of time were these: 1) interest vs. boredom, 2) filled vs. empty intervals, 3) repetition of an activy, and 4) activity vs. passivity. Loehlin concluded that time may seem long because the activity is boring, because attention is being paid to the passing of time, because the activity is unfamiliar, or because the subject is relatively passive.

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[267]Bruce Denner, Seymour Wapner, Joseph H. McFarland, and Heinz Werner, "Rhythmic Activity and the Perception of Time," American Journal of Psychology, LXXVI (June, 1963), pp. 287-292.

[268]John C. Loehlin, "The Influence of Different Activities on the Apparent Length of Time," Psychological Monographs, LXXIII (1959), pp. 1-27.

Berman[269] explored the belief that time passes slowly when a person is "statiated," i.e., when a subject rejects at least more than once an object or activity that was initially desired or pursued. An experimental group was satiated by having them work a maze; a control group worked the maze but was not satiated. Berman found that 87 per cent of the satiated group underestimated the time for them to become satiated. On the other hand, 52 per cent of the non-satiation group overestimated the time it took them to learn mazes. These findings seemed to be contradictory to what might have been expected, i.e., that time would pass slowly for the satiated group; therefore, Berman concluded that "a theory of satiation . . .in judgments of time does not seem to be warranted."[270]

Background effects.--Smith, Wing, and Jerison[271] gave subjects a two hour task and asked them to press a button every ten minutes. A training session was done in quiet, and an experimental session had the first half hour in quiet and the last hour and a half in noise. The results showed that the mean judgments were on the order of nine minutes in quiet and seven minutes in noise.

269Arthur Berman, "The Relation of Time Estimation to Satiation," Journal of Experimental Psychology, XXV (September, 1939), pp. 281-293.

270Ibid., p. 293.

271Arden K. Smith, Shelley Wing, and Harry J. Jerison, "Effect of Acoustic Noise on Time Judgment," American Psychologist, X (August, 1955), pp. 428-429.

Studying the effect of pitch upon the reproduction of temporal intervals, Triplett[272] found that there was a slight tendency for the intervals filled or surrounded by a higher pitch to seem longer than those filled or surrounded by a low pitch. Although the results were largely negative, Triplett felt that what effects there were might be explained by the pleasantness or unpleasantness of the pitch of the tones.

In another study on the effects of pitch Cohen, Hansel, and Sylvester[273] presented two tones of different frequencies to their subjects. By adjustment the subjects had to tell when the two tones seemed equal in duration. It was found that there was a tendency for the higher tones to seem shorter than the lower tones. This effect was more marked when the difference between the two tones was greatest.

Dreher and Evans[274] had subjects estimate and match durations of 1, 2, 4, 8, 16, and 32 seconds under alternating conditions of quiet and four types of high-level ambient noise. It was found that there was a significant underestimation of time in the environments of intense noise.

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[272] Ibid., p. 293.

[273] Cohen, Hansel, and Sylvester, loc. cit.

[274] John J. Dreher and William E. Evans, "Effects of Certain Auditory Environments on Protensity," Journal Accoustical Society of America, XXXIV (May, 1962), p. 739.

Frankenhaeuser[275] studied the effects of stimulus background by controlling the amount of change (a fast and a slow beat on a metronome) and by controlling the intensity of a constant auditory stimulus background (a 500 cycle tone). The objective second was subjectively longer when the amount of change increased; but there was no effect of the change in the intensity of the background tone.

Rhythm.--Dunlap[276, 277, 278, 279] has reviewed quite thoroughly the early studies on the relationships between time perception and rhythm. MacDougall[280] believes that the limiting sensations of an interval may cause a rhythmical effect. When there is a rhythmical sequence, accurate comparison is not possible, according to MacDougall.

Fraisse has commented on the fact that when ". . .the duration of an interval within a rhythmical group is changed, the apparent duration of the other intervals is modified."[281]

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[275]Frankenhaeuser, op. cit., p. 81.

[276]Knight Dunlap, "Rhythm and Time," Psychological Bulletin, VIII (July, 1911), pp. 239-242.

[277]Knight Dunlap, "Time and Rhythm," Psychological Bulletin, IX (May 1912), pp. 197-199.

[278]Knight Dunlap, "Time and Rhythm," Psychological Bulletin, XI (May, 1914), pp. 169-171.

[279]Knight Dunlap, "Time and Rhythm," Psychological Bulletin, XIII (May, 1916), pp. 206-208.

[280]MacDougall, "Rhythm, Time and Number," pp. 88-89.

[281]Fraisse, op. cit., p. 78.

He also indicates that a divided interval of discontinuous stimuli appears longer than an empty interval of the same duration. An evenly divided interval appears longer than one that is irregularly divided.[282]

It has been pointed out by Woodrow[283] that increasing the intensity in a series of equal temporal spacing causes a group-beginning effect; greater duration exerts a group-ending effect. Woodrow[284] has found that when there is a constant temporal rati between sounds and the absolute duration of one sound increases, there is an increase in its tendency to end the group.

Filled and empty intervals.--James[285] has stated that filled time seems longer than vacant time of the same duration. According to Fraisse[286], most authors agree that filled durations seem longer than empty durations even when they are physically equal; but, he stresses, this is true only if the empty interval follows the filled interval. Fraisse feels that the term empty duration has no sense; he does use the term, however, for the sake of convenience.

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[282] Ibid., pp. 132-133.

[283] Woodrow, "Time Perception," p. 1233.

[284] Herbert Woodrow, "A Quantitative Study of Rhythm," Archieves of Psychology, II (June, 1909), pp. 1-66.

[285] James, loc. cit.

[286] Fraisse, op. cit., p. 135.

This particular author[287] has found no significant difference in the reproduction of empty intervals and filled intervals. Wallace and Rabin[288] have said that the issue of filled *vs.* empty time has not been settled; however, they feel that the evidence indicates there is little significance in time estimation under the two conditions.

Whitely and Anderson[289] presented three different conditions to subjects: 1) no filling of the duration, 2) filling with a buzzer sound, and 3) filling with music. They found that when subjects were asked to estimate the elapsed time, the duration filled with music was judged to be shorter than the other two conditions. They felt that the judgments were influenced by a rhythmical factor. Spencer[290] found that poetry as a filler caused the interval to be judged longer than when prose or an empty interval was used. One difference between poetry and prose is the rhythm. This does not coincide with the reasoning of Whitely and Anderson, who said the rhythm of music caused the intervals to be judged shorter.

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[287] *Ibid.*

[288] Wallace and Rabin, *op. cit.*, p. 221.

[289] Paul L. Whitely and J. Carver Anderson, "The Influence of Two Different Interpolations upon Time Estimation," *Journal of General Psychology*, IV (December, 1930), pp. 391-401.

[290] Spencer, *loc. cit.*

Axel[291] asked subjects to estimate an empty interval and intervals filled with tapping, cancellation of numbers, working analogies, and a number series completion. When the interval was empty and when filled with tapping, subjects overestimated all intervals from 15 to 30 seconds. When the fillings were more difficult, the time intervals were underestimated.

Finding that all periods were overestimated whether they were filled or empty, Swift and McGeoch[292] concluded that there is little difference between unfilled intervals and intervals filled with interesting material. If the subject is doing something, however, time seems shorter than when he listens to somebody.

Instructions.--It has been pointed out in a previous section that time estimates vary according to how subjects go about judging. Woodrow[293] noted this in one experiment and felt that the instructions given to the judges would have a great effect upon the results. He took the introspective reports of this study and devised two sets of

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[291]Axel, op. cit., pp. 14-39.

[292]Edgar James Swift and John Alexander McGeoch, "An Experimental Study of the Perception of Filled and Empty Time," Journal of Experimental Psychology, VIII (June, 1925), pp. 240-249.

[293]Woodrow, "The Reproduction of Temporal Intervals," p. 496.

instructions to give to the judges.[294] In the first set subjects were to pay attention solely to the sounds and not to any effort of bodily movement. The second set of instructions had the subjects attending to bodily strain and movement. He found that reproductions were much longer on the average under the strain instructions than under the auditory instructions.

Duration And Speech

Gridley[295] has reported that subject discrimination of consonants is, in part, a discrimination on the basis of time. Some consonants have a "clipped-off" effect, whereas others have a "drawn-out" effect. Peterson and Lehiste[296] studied the influence of consonants upon the duration of stressed vowels and diphthongs. They found that the duration of a vowel (a syllable nuclei) was affected by the nature of the consonants following that vowel. The influence of the initial consonants upon the durations of the vowel appeared to be negligible. Vowels were shorter whorter when followed by a voiceless consonant and longer when followed by a voiced consonant. As a class,

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[294]Woodrow, "Individual Differences in the Reproduction of Temporal Intervals," pp. 277-281.

[295]Gridley, op. cit., p. 19.

[296]Gordon E. Peterson and Ilse Lehiste, "Duration of Syllable Nuclei in English," Journal Acoustical Society of America, XXXII (June, 1960), pp. 693-703.

plosives were preceded by the shortest vowels, but nasals had approximately the same effect. Vowels were longest before voiced fricatives. Two groups of vowels were noted: short vowels, [I, ɛ, ə , U], and long syllable nuclei, [e^{I}, æ , ɑ, ɔ , o^{U}, u, r, ɑ^{U}, ɑ^{I}, ɔ^{I}].

Schwartz[297] found that the longer a vowel is present, the less intense it had to be to be heard. Tiffany[298] also found that vowel identification varied as a function of the length of the vowel. He felt that vowels have a "natural" duration in speech; and the nearer a given vowel is to its natural duration, the easier it is to recognize. Because of this, Tiffany felt that duration may have a phonemic value.

Using consonant-vowel-consonant syllables, Stevens[299] had subjects identify vowels produced by a resonance analog. He found that distinctions between [i-I] and [u-U] were affected only slightly by vowel duration. The distinctions between [ɛ-æ] and [ʌ-ɑ], on the other hand, were strongly influenced by the duration of the vowel. When these vowels were presented in noise, the identification of them became

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[297]Martin F. Schwartz, "A Study of Thresholds of Identification for Vowels as a Function of Their Duration," Journal of Auditory Research, III (January, 1963), pp. 47-52.

[298]William R. Tiffany, "Vowel Recognition as a Function of Duration, Frequency Modulation and Phonetic Context," Journal of Speech and Hearing Disorders, XVIII (September, 1953), pp. 289-301.

[299]Kenneth N. Stevens, "Effect of Duration upon Vowel Identification," Journal Acoustical Society of America, XXXI (January, 1959), p. 109.

even more influenced by duration. Black[300] also constructed consonant-vowel-consonant syllables to study the interrelationships of frequency, intensity, and duration upon vowel identification. Although he found no significant interrelationship, he did find that the more open the vowel, the longer it was.

Noting that the length of time required to utter a sound is altered by the sounds preceding or following the sound, Oyer[301] set out to determine whether words composed of the same phonemes but differing in spelling and meaning will differ in duration. Using words that were identical in sound but differing in written form and meaning, he studied the semantic-orthographic influence upon the duration of homophones. He found that homophones with the same number of letters tended to be given equal time value. When the homophones differed in number of letters from their counterparts by one or two, duration values were less frequently significantly related than when the pairs of homophones contained the same number of letters.

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[300] John W. Black, "Natural Frequency, Duration, and Intensity of Vowels in Reading," Journal of Speech and Hearing Disorders, XIV (September, 1949), pp. 216-221.

[301] Herbert J. Oyer, "Duration of Homophones," Western Speech, XXIII (Spring, 1959), pp. 99-102.

Tiffin and Steer[302] found that stressed words differed from unstressed words in several aspects. One of these aspects was that in 98 per cent of the cases the stressed words were of longer duration. In another study on the interrelationships among pitch, intensity, and duration Ortleb[303] found that emphasized syllables had a longer duration than the unstressed syllables. The results of this study indicated that emphasis was not a function of any one factor but a combination of pitch, intensity, and duration.

In a study of syllable stress, Fry[304] used words that could be either nouns or verbs, depending upon the placement of stress. The judges' reports indicated that duration and intensity were both cues for judgments of stress but that duration was a more effective cue than intensity. He found that it was the vowel segments that showed the major differences in duration and intensity with a shift in stress.

Fairbanks and Hoaglin[305] simulated five emotions: contempt, anger, fear, grief, and indifference. They found

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[302]Joseph Tiffin and Max D. Steer, "An Experimental Analysis of Emphasis," Speech Monographs, IV (December, 1937), pp. 69-74.

[303]Ruth Ortleb, "An Objective Study of Emphasis in Oral Reading of Emotional and Unemotional Material," Speech Monographs, IV (December, 1937), pp. 56-68.

[304]D. B. Fry, "Duration and Intensity as Physical Correlates of Linguistic Stress," Journal Acoustical Society of America, XXVII (July, 1955), pp. 765-768.

[305]Grant Fairbanks and LeMar W. Hoaglin, "An Experimental Study of the Durational Characteristics of the Voice During the Expression of Emotion," Speech Monographs, VIII (December, 1941), pp. 85-90.

that the simulated emotions of anger, fear, and indifference had a rapid speaking rate and short duration of phonations and pauses. The emotions of contempt and grief had a slow rate, contempt being the slower of the two. The slow rate of contempt was produced by approximately equal prolongations of phonations and pauses. In grief the slow rate was caused by the prolongations of pauses.

Using the vowel [ɑ] at different frequencies and intensities, Ptacek and Sander[306] asked young adults to sustain a phonation as long as possible. They determined that maximum vowel duration was a function of both the frequency and the intensity of the phonation. Males, in general, could sustain phonation for a substantially longer duration than females. In another study[307] these same authors had subjects sustain the vowel [ɑ], and judges rated the segments for breathiness. The results showed that subjects who had relatively long phonations tended to be judged as less breathy than speakers with relatively short phonations.

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[306]Paul H. Ptacek and Eric K. Sander, "Maximum Duration of Phonation," Journal of Speech and Hearing Disorders, XXVIII (May, 1963), pp. 171-182.

[307]Paul H. Ptacek and Eric K. Sander, "Breathiness and Phonation Length," Journal of Speech and Hearing Disorders, XXVIII (August, 1963), pp. 267-272.

Hyman[308] asked cerebral palsied children and normal children to imitate words spoken by the experimenter. He found that, as groups, athetoids and normal children responded to variations in sound pressure, whereas the spastic group tended to be unresponsive and soft in sound pressure level. All three groups responded to variation in the duration of the stimuli, but Hyman found significant differences between cerebral palsied and normal children in the durational characteristics of speech.

Hanley and Steer[309] had subjects read a passage under four levels of noise to determine the effect of noise upon words-per-minute, syllable duration, and speech intensity level. They found that subjects reduced the rate of speaking, prolonged syllables, and spoke with greater intensity as noise increased.

Discussing another durational aspect in speaking--the opening and closing phases of the vocal cords--Van Riper and Irwin[310] state that closing of the vocal cords

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[308]Melvin Hyman, "An Experimental Study of Sound Pressure Level and Duration in the Speech of Cerebral Palsied Children," Journal of Speech and Hearing Disorders, XVII (September, 1952), pp. 295-300.

[309]T. D. Hanley and M. D. Steer, "Effect of Level of Distracting Noise upon Speaking Rate, Duration, and Intensity," Journal of Speech and Hearing Disorders, XIV (December, 1949), pp. 363-368.

[310]Charles Van Riper and John V. Irwin, Voice and Articulation (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1958), p. 447.

begins before phonation, in some cases several seconds before phonation begins. During normal phonation, closure comprises at least half of the cycle. As the pitch of the voice is raised and goes into falsetto, the duration of closure decreases.

Duration And Loudness

Lifshitz[311] has stated that the apparent duration of a sound impulse depends on its loudness. According to Wever and Lawrence[312], loudness increases progressively with duration up to a certain point. In studies of sounds well above threshold it has been found that the growth of loudness with duration nearly attains its maximum at 0.2 second.

Small, Brandt, and Cox[313] had subjects match a standard 500 millisecond burst for equal loudness. They found there was a "critical duration" below which it was necessary for subjects to increase the level of the short signal in order that it be judged equally loud. Above this

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[311] Samuel Lifshitz, "Apparent Duration of Sound Perception and Musical Optimum Reverberation," Journal Acoustical Society of America, VII (January, 1936), p. 213.

[312] Ernest Glen Wever and Merle Lawrence, Physiological Acoustics (Princeton, New Jersey: Princeton University Press, 1954), p. 64.

[313] Arnold M. Small, Jr., John F. Brandt, and Phillip G. Cox, "Loudness as a Function of Signal Duration," Journal Acoustical Society of America, XXXIV (April, 1962), pp. 513-514.

point loudness became independent of duration. This critical duration was 50 milliseconds for a 10 dB sound level standard; the critical duration decreased to 15 milliseconds for a tone of 60 dB.

Miller[314] found that the threshold of hearing is lowered by increasing the duration of the noise up to durations at least as long as one second. The loudness of an intense noise, however, depends upon its duration up to durations of only 65 milliseconds. These types of findings led Garner to state that "increasing the duration of a single tonal stimulus is one means of increasing total energy without changing intensity."[315]

In one study, however, Garner[316] found that when subjects were asked to match a 1000 cycle tone for loudness, some subjects showed a consistent change in loudness as a function of duration, whereas another group did not. He attributed this somewhat contradictory finding to either the methodology or the abruptness of the onset of the tone.

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[314]George A. Miller, "The Perception of Short Bursts of Noise," Journal Acoustical Society of America, XX (March, 1948), pp. 160-170.

[315]W. R. Garner, "Auditory Thresholds of Short Tones as a Function of Repetition Rates," Journal Acoustical Society of America, XIX (July, 1947), p. 600.

[316]W. R. Garner, "The Loudness and Loudness Matching of Short Tones," Journal Acoustical Society of America, XXI (July, 1949), pp. 398-403.

Summary

The many theories of time perception fall into five general categories. The theory that a <u>central nervous system mechanism</u> is the basis for time perception has as its primary tenet that there are either brain traces or memory traces remaining after a stimulus has ceased. These traces are later used for comparison with the durations of new stimuli.

A second theory proposes that an <u>internal clock mechanism</u> provides us with a "time sense," a sense comparable to the other senses. Other authors have suggested that <u>rhythmic bodily processes</u> give us cues for the perception of time. Some feel that the <u>amount of change</u> experienced alters the perception of time; for example, an increase in the number of changes may lengthen the apparent duration. A fifth theory states that there appears to be a period of time that is experienced as one event, i.e., a "<u>unity of organization</u>."

Studies have shown that the concept of time follows a developmental pattern. As a child develops, he becomes more aware of time and becomes better able to estimate time and to handle time concepts. The child has generally reached an adult level of time perception by the time he is 14 years of age.

Among the several problems that have received considerable attention in time studies are Weber's Law, the time-order error, the indifference interval, and the methods used in judging. The primary psychophysical methods employed in laboratory studies of time have been the methods of estimation, production, comparison, and reproduction. Recent studies have concentrated more on the last two.

Despite disagreement in some areas, most authors agree that individual differences are an important factor in time perception. Motivation, attitude, anxiety, amount of practice, age, and sex are individual factors that have been studied. The brain dysfunctions resulting from mental disturbance, mental retardation, and brain damage have also been found to cause aberrations in the perception of time.

Although several bodily functions have been explored, not all show the same degree of relationship to the experience of time. Among those discussed were physiological activity, strain and muscular activity, different sense modalities, pain, temperature, vaso-motor waves, thyroid activity, sleep, hypnosis, and drugs. The one that seems to have the greatest influence on time perception is strain and muscular activity. Several investigators have found that hearing seems to be the most important sense in the judgment of temporal intervals.

Varied conditions such as the serial position, the limiting sounds, background effects, the type of activity, the content of the interval, and instructions to subjects have all been shown to have some effect on time perception.

It was stressed that speech production has durational characteristics, and a relationship also exists between the duration and the loudness of a stimulus.

Consideration given to the several approaches to the study of time led to the development of the experimental procedures to be employed in the present study.

CHAPTER III

EXPERIMENTAL PROCEDURES

The method of reproduction was chosen for this experimental study because it gives the subjects active control over the response duration. Guilford[317] believes that this method is the "most natural" psychophysical method since the judgments are made by some action on the part of the subject. He feels that being able to control the stimulus creates a favorable attitude in the subject. Another advantage suggested by Guilford is that each trial gives a measurement; hence, there is an economy of time.

Selection of stimuli.--Five frequencies were chosen to be presented to the subjects: 250, 500, 1000, 2000, and 4000 cycles per second. These frequencies comprise the frequency range important for understanding speech[318] and seem to be the most sensitive frequencies for human beings. They also represent equal octave steps on the logarithmic frequency scale.

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[317]J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book company, Inc., 1954), p. 100.

[318]Hallowell Davis and S. Richard Silverman (eds.), Hearing and Deafness (New York: Holt, Rinehart and Winston, Inc., 1960), p. 52.

The five loudness levels at which the stimuli were presented were 40, 50, 60, 70, and 80 phons. Phons are loudness units based on the psychological interpretation of intensity. Fletcher and Munson[319] asked subjects to equate the loudness of various frequencies to the loudness of a 1000 cycle tone. From this loudness-matching they established equal-loudness contours, and the units of measurements were labelled phons. The levels chosen represent equidistant loudness levels from faint to loud.

For presenting these loudness levels to the subjects, it was necessary to determine the intensity equivalents in decibels (re 0.0002 dynes per square centimeter). The desired intensity levels were interpolated from the equal-loudness contours determined by Fletcher and Munson. The experimenter and one other person obtained the decibel equivalents for the five phon levels at the five chosen frequencies. The curves used for this interpolation are presented in Fletcher.[320] The greatest amount of disagreement between these two persons was 3 dB, an intensity difference that is hardly--if at all--detectable by the human ear.[321] This 3 dB difference occurred only once out of

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[319]Harvey Fletcher and W. A. Munson, "Loudness, Its Definition, Measurement, and Calculation," Journal Acoustical Society of America, V (October, 1933), pp. 82-108.

[320]Harvey Fletcher, Speech and Hearing in Communication (Princeton, New Jersey: D. Van Nostrand Company, Inc., 1958), pp. 186-187.

[321]Davis and Silverman, op. cit., p. 35.

25 measurements. Since the interpolations were not considered to be auditorily different, an average of the measurements by the two persons was taken as the intensity levels at which the sounds were to be presented. The average results of these measurements are presented in Table 1.

Fletcher and Munson used a 1000 cps tone as their reference tone; therefore, all phons at that level are the same as their intensity equivalents, i.e., 40, 50, 60, 70, and 80 phons.

TABLE 1.--The average interpolations for the intensity equivalents of phons given in decibels re 0.0002 dynes per square centimeter.

	Phons				
Frequencies	40	50	60	70	80
250	51	57	65	72	81
500	43	51	61	70	80
1000	40	50	60	70	80
2000	40	50	60	70	79
4000	38	48	58	67	75

Sounds were presented at five durations: 1, 3, 5, 7, and 9 seconds. The shortest duration chosen--one second--avoids one of the difficulties in the reproduction of temporal intervals, i.e., reaction time. Guilford[322] states that

[322]Guilford, *op. cit.*, p. 98.

although the reproduction method is convenient for the investigation of the perception of time, it should be used with some discretion. When the subject attempts to reproduce a standard time interval, reaction time enters into the response. He feels the error due to reaction time may be minor when the intervals are relatively large; but when the time intervals are small, the results may be jeopardized. It was important that the results of this experiment measure actual ability to reproduce a duration and not the subject's reaction times in depressing or releasing a key. In a preliminary trial it was found that it took approximately .3 second to depress and release a key. To insure that depressing and releasing a key did not affect the reproductions, the one second duration was chosen as the shortest to be used in this experiment.

It was also desirable that the durations of sounds studied be evenly spaced, but it was necessary to make certain that the durations were not too long. The experimenter wanted to keep all sounds within a "unity of duration;" by that is meant the interpretation of an experience as one event. Beyond unity the subject would experience a series of events, even though the stimulus might remain the same. From the results of previous research it was found that the upper limit of unity fell somewhwere in a range from 2.3 to 12.0 seconds.[323] The

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

time lengths chosen for the present study, then, represent durations that should not be affected adversely by reaction time nor by the experience of something more than unity; yet, the intervals are equally spaced.

With five frequencies, five loudness levels, and five durations a total of 125 combinations for the stimuli was possible. These 125 combinations were randomized (without replacement) by a table of random numbers.[324] Five different randomizations were made, and the individual subjects heard a different randomization at each session. Practice stimuli, presented before each experimental session, were randomized in the same manner.

Manner of presentation.--Each subject first read the instructions and was allowed to ask questions about them. A practice session with twenty practice stimuli was then held. After practice, the subjects were again allowed to ask questions. The stimuli resulting from the 125 randomized combinations of duration, frequency, and loudness were then presented one-by-one binaurally.

The stimulus was first presented to the subject; the subject was given 15 seconds in which to make his reproduction of the duration. The interstimulus interval (15 seconds) remained constant regardless of the duration of the stimulus

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[324]Wilfrid J. Dixon and Frank J. Massey, Jr., Introduction to Statistical Analysis (New York: McGraw-Hill Book Company, Inc., 1951), pp. 290-294.

in order to avoid the introduction of unknown variables. Fifteen seconds was found to be an adequate interval for responding to the durations presented. In a preliminary trial it was found that longer intervals tended to be underestimated; but even when the longest interval of nine seconds was overestimated in the trials, a fifteen second response interval allowed an ample duration for responding.

After the subjects had heard the stimulus, they were asked to depress a telegraph key and hold it down for as long as they thought the stimulus lasted. When the telegraph key was depressed, the subjects heard the same frequency and the same loudness that were heard during the stimulus interval. The only variable was the reproduction of the duration.

The following instructions were given to the judges:

> The task before you is the reproduction of time intervals. You are going to hear a series of tones of varied durations, frequencies, and loudness levels. The tone you will hear for each stimulus will be a continuous one; as soon as the tone ceases, you are to depress the telegraph key before you and hold it down for as long as you think the stimulus lasted. When you depress the key, you will hear the same pitch and the same loudness that you heard during the stimulus.
>
> This is not a test of reaction time; therefore, it is not important that you depress the key with great speed. Depression of the key too soon will cut off the tone, and you will not hear the entire stimulus. On the other hand, as soon as you are positive the stimulus has ceased, you may depress the key. There will be adequate time for you to make your reproductions of this duration; but the longer you wait, the more likely you are to make errors in your reproductions of the intervals. You do not have unlimited time to make your reproductions; and if you wait too long, you will cut off the next stimulus. Since you

need not rush your judgments but must respond within a reasonable period of time, the following suggestions are given to help you determine when to make your reproduction: As soon as you are sure the stimulus has ceased and as soon as you feel you can reproduce the time interval accurately, depress the key. Be careful not to depress the key accidentally, for this will interrupt the programming of the presentations.

The intervals between stimuli will be the same. Sometimes you will have a short period to wait after your reproduction; 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 is to occur. The onset of the stimulus will be your alerting signal. Try to stay prepared throughout the entire test for the onset of the stimuli.

You are to judge only on the experience of duration. 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. Make every effort to avoid such things as counting to yourself (1001, 1002, 1003, etc); looking at your watch; making rhythmical movements with your hands, feet, or tongue; counting your inhalations and exhalations. This is a test of your ability to reproduct temporal intervals, not of your ability to count off segments of time. Pay attention only to the sensation of duration.

You will first hear twenty stimuli for practice. If there are any questions regarding your task, ask them during or after this warm-up period. Do not ask questions during the test itself. There will be 125 stimuli on the test.

The results of measurement with a sound level meter showed that the ambient room noise at the subject's ear level outside the earphone cushions was, on the average, 51 dB (re 0.0002 dynes per square centimeter).

Apparatus.--The following instruments were used for recording the stimuli and for presenting the stimuli to the subjects:

1. 3M magnetic recording tape, Type 203
2. Hewlitt-Packard Low Frequency Oscillator, Model 202-C

3. Ampex Tape Recorder, Model 601-2
4. Hunter Timer, Model 100-C, Series D
5. Ampex Mixer, Model MX-35
6. Ampex Line Amplifiers, Model 620
7. Bruel and Kjaer Electronic Voltmeter, Type 2409
8. Bruel and Kjaer Sound Level Meter, Type 2203
9. Telephonics earphones, Model TDH-39
10. Hughes Aircraft Timer Stop-Computer, Model J 9101
11. Dressen-Barnes 24 volt power supply Model .28-2MX.

Recording of the stimuli.--The practice stimuli and the stimuli for the experiment itself were placed on magnetic recording tape. The stimulus tone to be recorded was generated by the low frequency oscillator. The signal was timed by the Hunter Timer and sent into Line One of the tape recorder. The stimulus next went into Line One of the mixer. At this point the signal was amplified by the mixer and further by the line amplifiers. The signal was monitored on the voltmeter. When the stimulus duration had ceased, the Hunter Timer automatically switched the tone from Line One of the tape recorder to Line Two of the tape recorder. This tone was sent through Line Two of the mixer, amplified, and monitored on the voltmeter. The entire system had previously been calibrated with the sound level meter through the earphones to be used in the study. The reading on the voltmeter, therefore, represented the level to be heard by the subjects through the earphones. A block diagram of the recording instrumentation is shown in Figure 1.

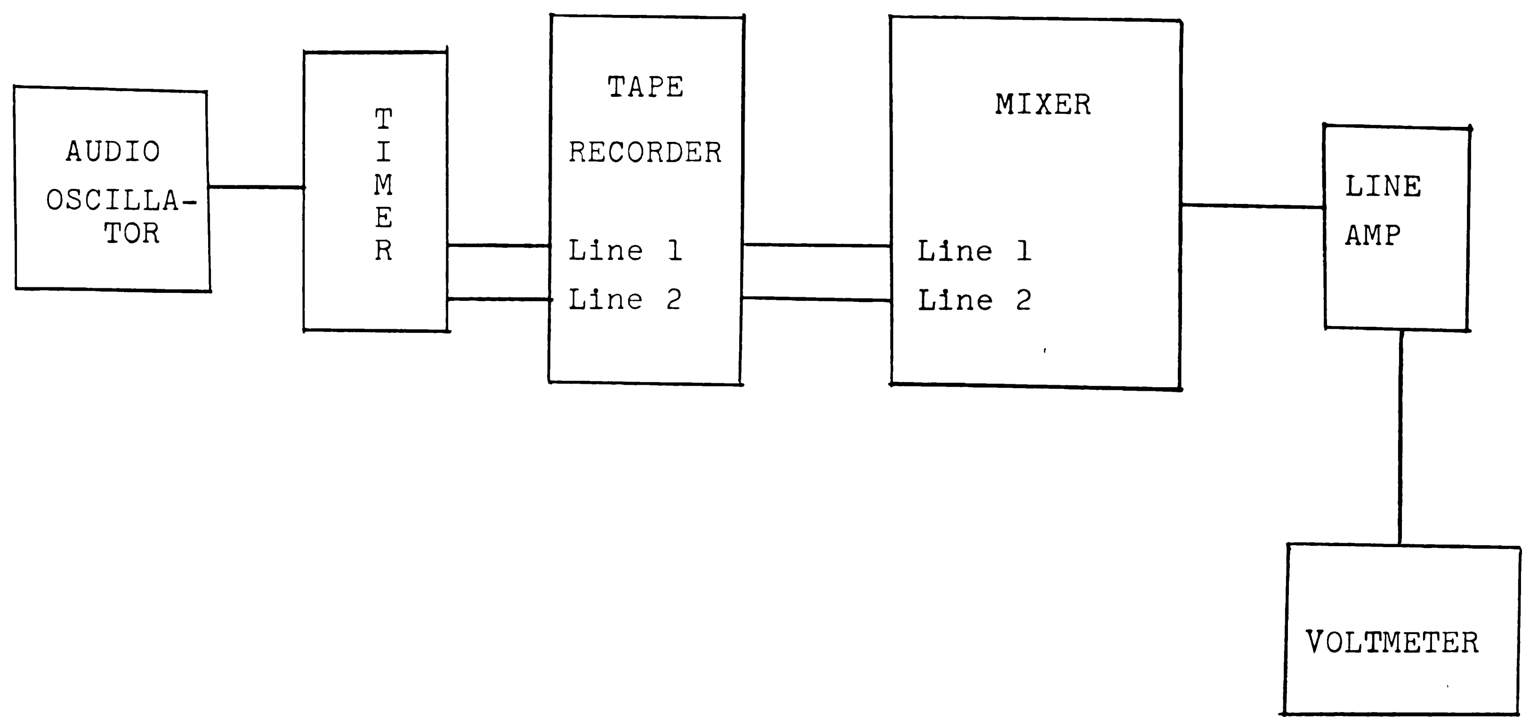

FIGURE 1.--Block diagram of recording apparatus.

The actual duration of the stimulus tone recorded on tape was accurate--on the average--to .18% of the intended duration. The tone for the stimulus interval was recorded on Channel One of the tape recorder, whereas the response interval tone was recorded on Channel Two. The Hunter Timer was used to time the stimulus duration; the Hughes Aircraft Timer was used to time the taped duration of the response interval.

Response to the stimuli.--The taped stimuli were played through Channel One of the tape recorder into Line One of the mixer. The signal was sent through Outputs A and B simultaneously to the earphones. When the subject depressed a telegraph key, Channel Two of the tape recorder was opened and the subject heard the tone present during his response. This tone was sent through Line Two of the mixer and again presented binaurally through Outputs A and B. Depression of the key also started the Hughes Aircraft Timer that was used to time the duration of the responses. This timer was run by the Dressen-Barnes power supply. A block diagram of the instrumentation for the response is shown in Figure 2.

Subject selection.--Five subjects were selected as judges in this experiment. Four of the subjects were graduate students in Speech and Hearing Science at Michigan State University; the fifth subject was a senior staff member in Speech and Hearing Science at the institution.

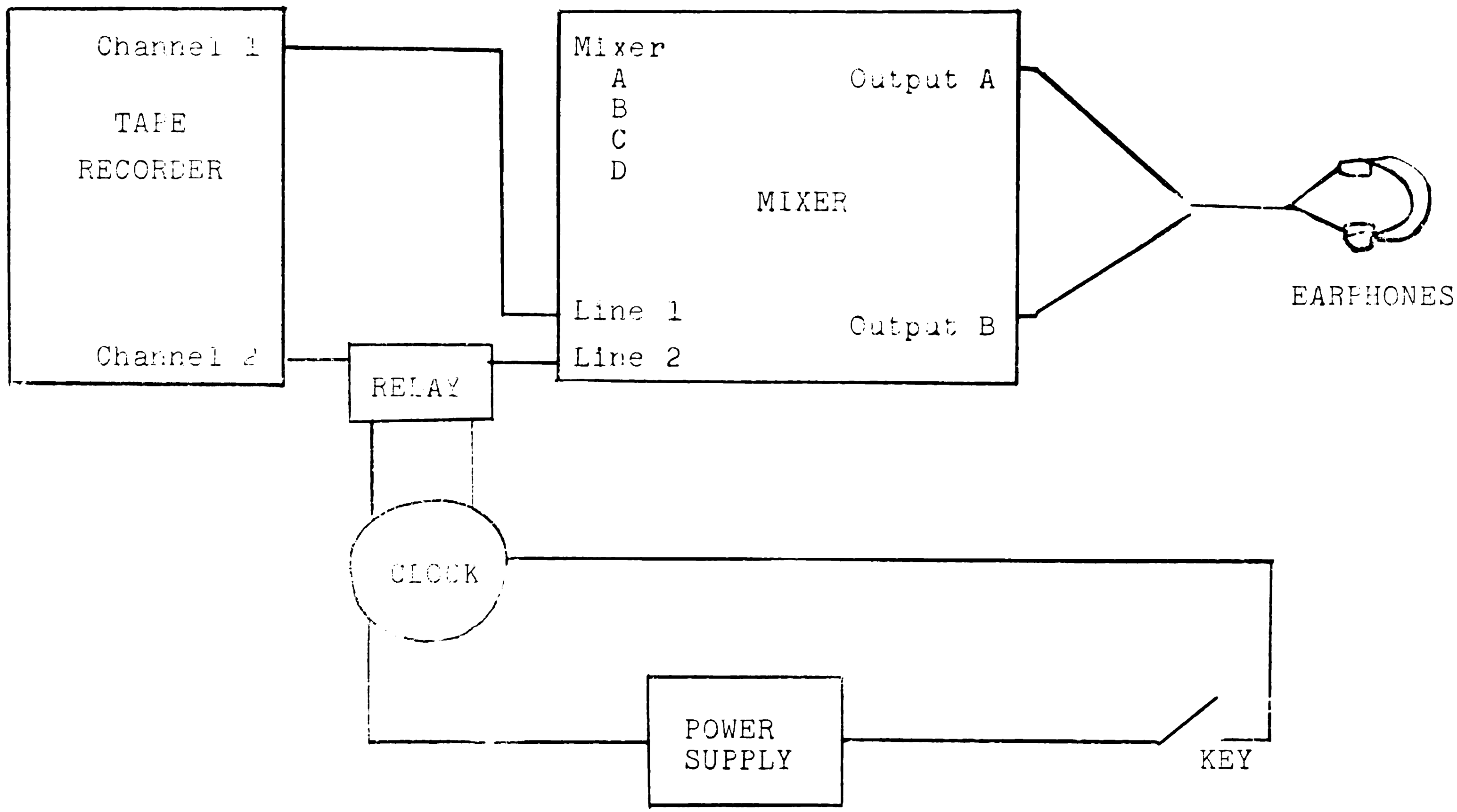

FIGURE 2.--Block diagram of instrumentation for the experimental sessions

The ages of the subjects were as follows: 26, 26, 32, 33, and 43. All five subjects were experienced in experimental procedures. Each subject had a hearing level of at least + 15 dB (re audiometric zero) in each ear at the frequencies used in the study, i.e., 250, 500, 1000, 2000, and 4000 cycles per second.

Training of subjects.--Since it was assumed that the task in this experiment would involve learning, it was necessary to adopt a criterion of saturation of learning. If learning in this task followed typical learning curves, there would be an initial period of acceleration of learning followed by a plateau. With this in mind, the criteria set for this expected asymptote were as follows: when, on two successive trials, the subjects' mean reproductions were not significantly different and showed a correlation of .90, they would be accepted as "trained" subjects. The formulae used for the *t*-test for related means and for the test of correlation are found in Blalock.[325]

Four of the five subjects met these criteria on the first two trials. The other subject did not reach this asymptote until the second and third trials. Table 2 shows the results of the *t*-tests and the tests for correlation. The data used to compute these statistics are found in Appendix A.

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[325]Hubert M. Blalock, Jr., Social Statistics (New York: McGraw-Hill Book Company, 1960), p. 181, p. 289.

TABLE 2.--Results of the *t*-test and test for correlation on two successive experimental sessions to determine acceptability of subjects.

Subject	*t**	*r*
1	1.78	.94
2	.50	.93
3	1.35	.97
4	1.25	.88**
5	.64	.93

* *t* of 1.96 significant at the 5% level of confidence

** *r* of .88 not significantly different from *r* of .90 as measured by Fisher's Z.[326]

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[326]John Gray Peatman, *Descriptive and Sampling Statistics* (New York: Harper and Brothers Publishers, 1947), p. 386.

CHAPTER IV

RESULTS AND DISCUSSION

Results

As was discussed in Chapter III, each subject reproduced the duration of stimuli consisting of 125 combinations of duration, frequency, and loudness at each experimental session. When the subject had two consecutive sessions showing no significant difference between means and a correlation of +.90, he was considered as an acceptable subject for this study.

Using the reproductions of these two consecutive sessions, the experimenter employed the following procedure to establish the raw data for analysis: The difference-time (ΔT) was established by finding the difference between the actual stimulus duration on the tape and the subject's reproduction of that duration. The difference-time was then divided by the actual duration of the stimulus. The resulting ratio, therefore, was $\frac{\Delta T}{T}$. The sign of the reproduction was always kept in making these computations. If the reproduction was shorter than the stimulus duration (that is, underestimated), the ratio carried a minus sign; if the reproduction was longer than the stimulus duration (that is, overestimated), the ratio carried a plus sign.

This method of treatment avoided the problem of putting too much emphasis on the size of error in comparison with the actual duration. In other words, it was felt that a difference-time of .05 second was not of the same magnitude for one second as it was for nine seconds.

Since each stimulus appeared twice--once each for the last two experimental sessions--the mean of these two reproductions was used as that subject's score for that particular combination of duration, frequency, and loudness. Each subject, therefore, had a total of one-hundred and twenty-five averaged reproductions. The averaged raw data are found in Appendix B.

The F-Max test.--Before submitting these data to an analysis of variance to determine whether there were significant differences in subject response among the durations, frequencies, and loudness levels, it was necessary to check one of the assumptions of an analysis of variance--homogeneity of variance. In order to determine whether there was homogeneity of variance for duration, for frequency, and for loudness, an F-Max test was computed.[327] The results of this test are found in Table 3.

The results of the F-Max test indicate that all three variables--duration, frequency, and loudness--lacked

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[327] Dixon and Massey, op. cit., p. 20.

TABLE 3.--Variances used to compute the F-Max tests for homogeneity of variance for duration, for frequency, and for loudness.

Duration	Variance	Frequency	Variance	Loudness	Variance
1 sec.	.065	250 cps	.048	40 phons	.064
3 sec.	.019	500 cps	.044	50 phons	.052
5 sec.	.013	1000 cps	.047	60 phons	.041
7 sec.	.020	2000 cps	.058	70 phons	.050
9 sec.	.017	4000 cps	.065	80 phons	.053
F-Max = 5 0*		F-Max = 1.477*		F-Max = 1.56*	

N = 125

* F of 1.39 significant at the 1% level of confidence[328]

homogeneity of variance. The variances for duration showed this lack of homogeneity to a greater degree than did the variances for frequency and loudness. The assumption of homogeneity of variance, therefore, could not be made in this case. The high F-Max in the case of duration was caused primarily from the large variance for one second. If the variance for one second is not considered and another F-Max test computed, the resulting F is 1.54. This means that, even when only the durations of three, five, seven, and nine seconds are used in the F-Max test, the variances are still not homogeneous.

[328]George A. Ferguson, Statistical Analysis in Psychology and Education (New York: McGraw-Hill Book Company, Inc., 1959), pp. 310-313.

Linquist[329] cites a study by Norton, however, which studied the effects of non-normality and heterogeneity of variance. Norton found that

> . . .unless the heterogeneity of either form or variance is so extreme as to be readily apparent upon inspection of the data, the effect upon the F-distribution will probably be negligible. In general, when the heterogeneity in form or variance is "marked" but not "extreme," allowance may be made for this fact by setting a higher "apparent" level of significance for the tests of treatment effects than would otherwise be employed.[330]

With this in mind, the 1% level of significance was chosen over the 5% level of significance.

On the basis of the Norton study, it was decided that even though there was lack of homogeneity, an analysis of variance would be employed. It should be understood, therefore, that the results in the present study must be read with the fact in mind that the experimenter was willing to break the assumption of homogeneity of variance.

The analysis of variance --The data were subjected to a factoral design (5 x 5 x 5) analysis of variance. An analysis of variance routine (FACREP, Option 3) for the CDC 3600 computer was employed.[331] The results of this analysis are found in Table 4.

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[329] E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education (Boston: Houghton Mifflin Company, 1953), pp. 78-88.

[330] Ibid., p. 86.

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

TABLE 4.--Summary table for the factorial design analysis of variance.

Source of Variance	Sum of Squares	DF	Mean Square	F Statistic	Sign. at 1% Level[332]
DURATION (D)	15.94116640	4	3.98529160	134.03327	3.34
FREQUENCY (F)	.13473440	4	.03368360	1.13285	3.34
D X F	.33302720	16	.02081420	.70002	2.77
LOUDNESS (L)	.26459680	4	.06614920	2.22473	3.34
D X L	.29686080	16	.01855380	.62400	2.77
F X L	.11550080	16	.00721880	.24278	2.77
D X F X L	.61800960	64	.00965640	.32476	1.60
ERROR	14.86679999	500	.02973360		
TOTAL	32.57069599	624			

The results of this analysis showed that the only variable showing significance was that of duration. There were no significant differences in subject responses among the different frequencies nor among the different loudness levels, and there were no significant interactions among or between the variables of duration, frequency, and loudness. The following hypothesis was, therefore, rejected:

1. There is no significant difference in a subject's ability to reproduce temporal intervals of five different durations: 1 second, 3 seconds, 5 seconds, 7 seconds, and 9 seconds.

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[332] Ferguson, loc. cit.

The following hypotheses were not rejected:

2. There is no significant difference in a subject's ability to reproduce temporal intervals of five different frequencies: 250 cycles per second, 500 cps, 1000 cps, 2000 cps, and 4000 cps.
3. There is no significant difference in a subject's ability to reproduce temporal intervals of five different loudnesses: 40 phons, 50 phons, 60 phons, 70 phons, and 80 phons.
4. There is no significant interaction between duration and frequency in a subject's ability to reproduce temporal intervals.
5. There is no significang interaction between duration and loudness in a subject's ability to reproduce temporal intervals.
6. There is no significant interaction between frequency and loudness in a subject's ability to reproduce temporal intervals.
7. There is no significant interaction among duration, frequency, and loudness in a subject's ability to reproduce temporal intervals.

The differences, in terms of $\frac{\Delta T}{T}$, among the responses to the durations can be seen in Figure 3 The means and standard deviations used to plot the curves in Figure 3 are found in Table 5. The large deviation for one second is visually evident on the graph. Since the variables of frequency and loudness had no effect upon the reproductions and since there were no significant interactions whatsoever, the data have been combined to show the effects of duration only. In order to determine where the differences lay among the different durations, a critical difference test[333]

[333] Lindquist, op. cit., pp. 90-96.

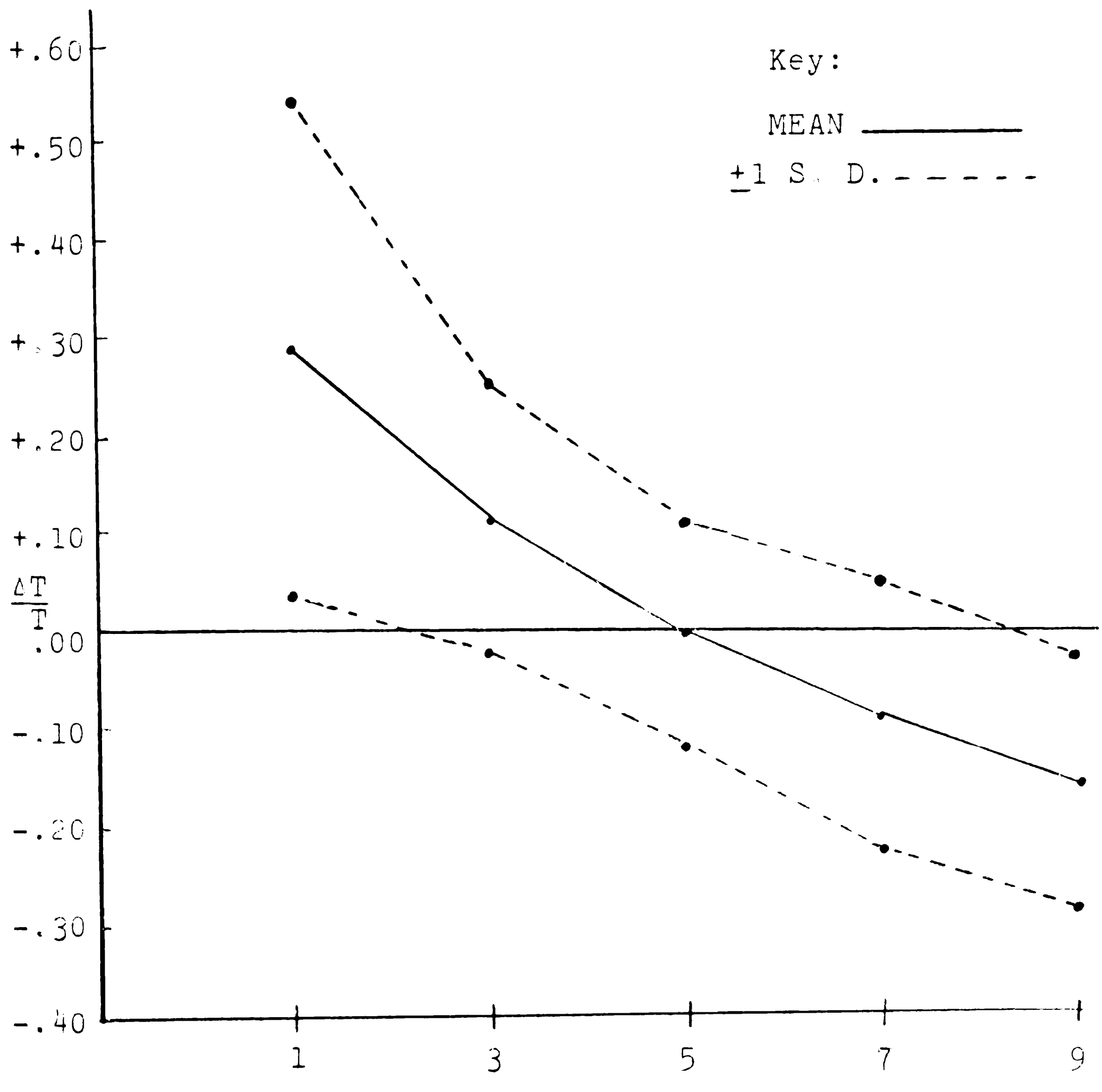

FIGURE 3.-- $\frac{\Delta T}{T}$ Plotted as a function of duration showing means and standard deviations of reproduced temporal intervals.

TABLE 5.--Computed means and standard deviations of the reproductions of each stimulus duration.

Seconds	Mean	Standard Deviation
1	+.28656	.25504302
3	+.11112	.13893150
5	-.00768	.11408214
7	-.09512	.13996898
9	-.16528	.13097387

was employed. It was found that a difference between two means of more than .056244 would be significant. The results of this test are shown in Table 6. The critical

TABLE 6.--Critical differences between the means of reproduction times.

Means		Differences			
		3 sec.	5 sec.	7 sec.	9 sec.
1 sec. = +.28656	1 sec.	.17544*	.29424*	.38168*	.45184*
3 sec. = +.11112	3 sec.		.11880*	.20624*	.27700*
5 sec. = -.00768	5 sec.			.08744*	.15760*
7 sec. = -.09512	7 sec.				.07016*
9 sec. = -.16528					

* Difference between two means significant at the 1% level of confidence.

difference test revealed, therefore, that significant differences existed between each possible pair of durations.

Discussion

Weber's law.--As was stated in Chapter II, there have been conflicting reports on the application of Weber's Law to the judgment of time. Some researchers have found that this ratio ($\frac{\Delta T}{T}$) did not apply to time. If this ratio did equal a constant, as Weber indicated, then the curve in Figure 3 would be flat. In the present study Weber's Law does not appear to hold, since the curve plotted in Figure 3 does not seem to flatten out in any area.

Some researchers, on the other hand, have found Weber's Law holding for certain circumstances. Gilliland[334] found that Weber's Law seemed to hold for durations of 4-27 seconds, and Henry[335] noted a decrease in the Weber ratio as duration increased. On the basis of these studies, one might expect a high ratio at the shorter durations and a lower ratio at the longer durations. The phenomena are also evident in the present study. By closely surveying Figure 3 and by looking at the critical difference scores in Table 6, it would appear that there may also be a slight leveling off of the curve representing the Weber ratio for the longer durations. Such

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

[335] Henry, op. cit., pp. 737-739.

a leveling off would be expected if the underestimations were extremely large. The largest $\frac{\Delta T}{T}$ possible in the case of overestimation is infinity, but in the case of underestimation the largest $\frac{\Delta T}{T}$ possible is only 1.0. Failure to reproduce the interval would result in a ratio of 1.0. In other words, if reproductions of the long intervals were extremely short, one would expect to see the beginning of a flattening of the curve representing $\frac{\Delta T}{T}$.

The time-order error.--Referring to Figure 3, it can easily be seen that--on the average--the durations of one and three seconds tended to be overestimated and the durations of seven and nine seconds tended to be underestimated. This finding would support Vierordt's Law, which states that short intervals are overestimated and long intervals are underestimated; nevertheless, when one considers the actual reproductions and not the average, one would have to agree with Woodrow,[336] who found that all intervals are overestimated sometimes and underestimated other times. Not all short intervals were always overestimated, and not all long intervals were always underestimated.

The indifference point.--The indifference point in this study would be the place where the stimulus durations were neither overestimated nor underestimated, i. e., where the $\frac{\Delta T}{T}$ is equal to zero.

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[336]Woodrow, "The Reproduction of Temporal Intervals," pp. 473-474.

That point, established by linear interpolation, is 4.90 seconds. Woodrow[337] has stated that the indifference interval of 0.5 to 0.7 second has been reported more than others. In the present study, the indifference point of 4.90 seconds lies well above these points. It will be recalled, however, that some authors have suggested there is a central tendency influence in a long experiment, i. e., there is a tendency for the judges to judge against the average of the range of stimuli used. Such would appear to be the case in the present study. The indifference point is located only slightly below the middle of the range of durations used.

The indifference point for this study was determined by the mean of the five subjects. Subject indifference points varied, however, from approximately 3.20 to 7.65 seconds. This would remind us of Stott's[338] contention that subjects play a great part in the determination of an indifference interval. Two of the subjects had indifferent points below five seconds and three subjects had indifference points above five seconds.

<u>Effects of frequency and loudness</u>.--Fraisse[339] has mentioned that in the case of brief filled durations the more intense the sound is, the longer it will seem; for longer

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337 Woodrow, "Time Perception," p. 1226.

338 Stott, <u>op. cit.</u>, pp. 743-744.

339 Fraisse, <u>op. cit.</u>, pp. 130-134.

durations the effect of intensity upon apparent duration decreases. Hirsh, Bilger, and Deatherage[340] found that reproductions were longer when reproduced in noise. Wallace and Rabin[341] also report that if the intensity of a sound is increased during an interval, the duration tends to be overestimated.

Fraisse[342] also noted that the frequency of the limiting sounds affects the apparent length of an interval. A study by Triplett[343] showed that a sound of high pitch seems longer than a deep sound. On the other hand, Cohen, Hansel, and Sylvester[344] found a tendency for higher tones to seem shorter than low tones.

Since different studies have used different durations, different loudness levels, and different frequencies, it is understood that there cannot always be a direct comparison among studies. The results of the present study, however, indicate that, at least within the range of frequencies and loudnesses studied, there is no effect of these stimulus parameters upon the reproduction of durations. It very well could be, of course, that extending the range of frequencies and loudnesses might show greater effects upon the

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[340] Hirsh, Bilger, and Deatherage, _op. cit._, pp. 561-574.

[341] Wallace and Rabin, _op. cit._, p. 220.

[342] Fraisse, _op. cit._, p. 130.

[343] Triplett, _op. cit._, pp. 201-265.

[344] Cohen, Hansel, and Sylvester, _op. cit._, pp. 642-646.

interpretation of duration. For example, sounds nearer discomfort level than those used in the present experiment might affect the reproductions. The results shown in this paper, however, give no indication that this would occur.

Subject differences.--By use of explicit instructions it was hoped that some of the expected subject variability could be controlled. Specifically, the subjects were asked to avoid counting and using rhythmical movements of the body. Subjects reported that they found it difficult not to count; all felt, however, that they had followed the instructions explicitly. After the experimental trials were completed, most subjects found it difficult to describe just what methods they had used in reproducing the intervals. One subject did say that he tried to catch the duration "out there." This particular subject was one who tended to make his reproductions shorter--that is, to underestimate--the durations. This follows the pattern noted by Woodrow:[345] when subjects reproduce intervals in an automatic manner, the reproductions tend to be short.

Some of the subjects suggested that they found it difficult to concentrate on some of the tones. This comment possibly would suggest that some of the durations--probably the longer ones--extended beyond the "unity of duration."

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

As had been expected, the task resulted in subject variation. Subjects One and Two seemed to experience duration in a similar manner, for both tended to underestimate the durations. Subjects Three, Four, and Five all made similar judgments by tending to overestimate the durations.

Serial position.--Since the effects of serial position had been noted in some previous studies, the question was raised whether subjects were any better in their judgments in a particular portion of the series than in another portion. For a check of this possible effect, the last session for each subject was chosen for study. The first 62 stimuli in the series of 125 were compared with the last 62 stimuli in the same experimental session. These data were analyzed by a *t*-test programmed for the CDC 3600 computer. The results of this analysis are found in Table 7.

From the analysis of this comparison it can be seen that there were no significant differences for any of the subjects between the first half and the second half of the experimental session. This would indicate that serial position had no significant effect in this study.

TABLE 7.--Differences between temporal reproductions in the first half and in the second half of the last experimental session.

Subject	t*
1	-0.84228
2	-1.37867
3	-0.79643
4	-0.44857
5	-0.40711

* t of 1.98 necessary for significance at the 5% level of confidence.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The topic of time can be viewed in two basic ways; objectively and subjectively. In the objective view, prime consideration is given to the physical units of time. In the subjective view, prime consideration is given to the psychological interpretation of time. Several discourses exist regarding the nature of time--both from the physical and from the psychological standpoint. In spite of the fact that much research has been accomplished in the study of time perception, results have often been contradictory. A review of the writings on the interpretation of time indicates that time perception appears to be an individual phenomenon. Although not all authors agree on how time is perceived, most believe that time perception is individualistic in nature.

Much has also been written regarding the effects of the content of the interval upon the interpretation of time. There have been few studies, however, that have treated the temporal interrelationships of the parameters of a pure tone auditory stimulus, i. e., frequency, intensity, and duration. Some have suggested that the louder a sound is, the longer it will seem. It has also been noted that a sound of high pitch seems longer than a sound of low pitch. Others have found that intervals of short duration are more accurately perceived than long intervals of time. The results of research regarding these parameters, nevertheless, have been conflicting.

The purpose of the present study was to examine the effects of duration, frequency, and loudness upon the ability of subjects to reproduce temporal intervals. Specifically, it was asked whether the frequency, the loudness level, or the duration of a pure tone stimulus has any influence over the reproduction of the duration of that stimulus. In addition, the question was raised whether there might be inter-relationships among these three parameters that might affect the reproduction of the temporal intervals.

Pure tones of either 250, 500, 1000, 2000, or 4000 cycles per second at loudness levels of 40, 50, 60, 70, or 80 phons were presented to subjects at five different durations: 1, 3, 5, 7, and 9 seconds. One-hundred and twenty-five stimuli, consisting of different combinations of duration, frequency, and loudness, were placed on magnetic recording tape to be presented to the subjects. Different randomizations of these combinations were presented to normal hearing subjects on successive days until the subject's reproductions on two consecutive experimental sessions were not significantly different and showed a correlation of at least +.90.

Each subject heard a stimulus for a specified duration. He then depressed a telegraph key to reproduce what he perceived to be the duration of that interval. The same procedure was employed throughout the 125 stimulus combinations. During the period of reproduction the subjects heard the same frequency at the same loudness level that was present during the stimulus interval.

The difference-time between the actual duration of the stimulus and the time of reproduction was computed. This figure was divided by the duration of the stimulus. The resulting ratio to be used in the analysis was, therefore, $\frac{\Delta T}{T}$. If the reproduction was shorter than the stimulus duration, the ratio carried a minus sign; if the reproduction was longer, the ratio carried a plus sign. The mean of the last two experimental sessions was used as the subject's score for each particular combination of duration, frequency, and loudness.

An F-Max test was computed, and it was found that there was a lack of homogeneity of variance for each of the three stimulus parameters. Norton[346] has indicated, however, that lack of homogeneity of variance probably has a negligible effect upon an analysis of variance. With this study as support, the experimenter proceeded

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[346]Lindquist, _op. cit._, pp. 78-88.

with a factorial design analysis of variance. The results of this analysis showed that the only significant variable employed in this study was duration. The parameters of frequency and loudness had little or no effect upon the subjects' abilities to reproduce the time lengths employed. In addition, there were no combined effects among the three variables. A critical difference test was computed to determine where among the five durations the differences lay. It was found that differences existed between all possible combinations of durations.

In this study there was a tendency for subjects to overestimate intervals of one and three seconds and to underestimate intervals of seven and nine seconds. The five second interval represented what has traditionally been designated the indifference interval, the actual indifference point being 4.90 seconds.

Conclusions

Within the limitations of the present study, the following conclusions seem to be warranted:

1. Neither the frequency nor the loudness level of a pure-tone stimulus affects a subject's ability to reproduce temporal intervals. At least for the ranges of frequency and loudness used, it is apparent that the acoustic content of the interval had no detrimental effect upon the reproduction of duration. The duration of

a tone that is only slightly above detection threshold is perceived in the same way as the duration of a relatively loud tone, and the duration of a low-pitched tone is perceived in the same manner as the duration of a higher-pitched tone.

2. Reproduction of filled temporal intervals <u>is</u> affected by the duration of the stimulus. On the average, the durations of one and three seconds resulted in overestimations of the intervals and the durations of seven and nine seconds resulted in underestimations of the intervals; the five-second duration was neither overestimated nor underestimated. All durations, however, were at one time or another both overestimated and underestimated. Differences in temporal interpretation of pure-tone stimuli existed between all possible pairs of durations employed. The duration of one second appeared to be more difficult to reproduce accurately than the durations of three, five, seven, or nine seconds.

3. The $\frac{\Delta T}{T}$ for short durations is greater than the $\frac{\Delta T}{T}$ for long durations. The curve representing this ratio is relatively linear from a positive ratio for one and three seconds through an indifference point near five seconds to a negative ratio for seven and nine seconds. On this basis it can be concluded that, in this particular experimental circumstance, Weber's Law does not appear to hold for the reproduction of temporal intervals.

4 The obtained indifference interval of 4.90 seconds falls very near the middle of the duration range employed, a fact indicating that the central tendency factor was operating in this experiment. This finding supports previous reports that in a long experiment where a wide range of durations is used, the indifference point tends to occur in the middle of the range.

5. Serial position has no effect upon subject reproductions of durations composed of pure-tone auditory stimuli. Reproductions of the durations were essentially the same whether the stimulus occurred in the first half or the last half of the experimental session.

Implications for Further Research

Even though much has been accomplished in the study of time perception, several new or related studies need to be pursued. Some could be undertaken to further the knowledge of the aspects of normal time perception. Beyond that goal is the possibility of studying abnormal, or disordered, time perception. The following specific areas are suggested for adding to the general knowledge of time perception.

The use of different psychophysical methods.--As has been noted previously, different psychophysical methods have been employed in the study of time; and results have not always coincided. Studies similar to the present one--utilizing the same durations, frequencies, and loudness levels--could be designed to determine whether other methods would show the same trends.

Changing the content of the interval.--The stimulus ranges used in the present study could be extended. Tones of greater or lesser intensity, higher or lower frequency, and longer or shorter duration could be employed to determine whether or not the same results and trends would be obtained.

Pure tones were used as stimuli in this study, but there is a possibility that different types of acoustic stimuli would change the interpretations of time. For example, one might ask whether complex tones--either harmonic or inharmonic--would help or interfere with the judgment of duration. Such varied stimuli as white noise, saw-tooth noise, environmental noises, music, and speech could be used as filling for the intervals to be judged. In addition, the acoustic stimuli would not have to be continuous as they were in this case; warbled tones, pulsed tones, and different rhythmic patterns could also be employed. In the case of rhythmic patterns, the intervals could be judged on their overall duration or the rhythmic pattern itself could be reproduced

Individual differences.--The age range of the subjects used in this study was somewhat restricted--from 26 to 43. One might question whether younger subjects and older subjects would respond in the same manner. The possibility of different responses to time in the aging is especially intriguing. Would the empirical evidence for a change in time perception in the aging appear in the results of laboratory experiments as well?

Increasing the number of subjects and having each subject reproduce just one duration several times would eliminate the central tendency factor. This method of experimentation might alter the results found in the present study. Experiments could also be performed to determine whether there is any correlation between personality factors and the way in which time is perceived.

Time perception in speech and hearing disorders.--The possibility of disturbances in time perception in speech and hearing disorders suggests the need for further study in this area. One of the early considerations in chosing the present study was the possibility that time perception might be a much neglected factor in the study of speech production and sound perception. The experiment was undertaken with the idea in mind that it might be one of a series of experiments leading to a diagnostic test to be added to our current battery of tests. Comparisons between normal subjects and subjects with speech disorders, hearing disorders, or both could then be made.

Before such a test could be proven to be a valuable tool, further research is obviously necessary. If the procedures of the present study were to be used, it would be unnecessary to retain the various frequencies and loudness levels. One frequency and one loudness (perhaps 1000 cps at 60 phons) would be sufficient. It is not certain, however, that the interval content employed in this study would be the most discriminating. Some of the studies mentioned previously would aid in making such decisions.

The psychophysical method used in constructing such a test must also receive prime consideration, for this test would have to employ procedures that most people could perform without difficulty. Whatever the decision on the psychophysical method used, most of the following suggestions could be adapted to the method.

Several authors have suggested the presence of disturbed time perception in the brain damaged, specifically in the symbolic disturbance of aphasia. The results of research in this area might add to our arsenal of testing and therapeutic techniques.

Stuttering, with its arhythmic speech patterns, is another disorder that might be studied by a time perception test. Perhaps a disturbance in time perception is related to the disturbance in rhythmical speech production. The same might be said of voice disorders, especially those that show a poor timing of the opening and closing phases of the vocal cords.

It is certainly not inconceivable that cases of articulation disorders might show disturbances of time perception. Let us suppose that a person underestimates the length of some phonemes. This shortened perception could adversely affect the learning of these sounds. Being able to identify such possible difficulties might aid in making a prognosis.

Possibilities for future studies in the case of hearing loss are also practically unlimited. It is well-known that hard-of-hearing persons are disturbed in receiving or perceiving loudness and pitch. Little is known about their perception of duration. The reported loss of "life's on-going character" in the deaf suggests that personality factors as well as physiological factors may be involved in their time perception.

There are no studies to indicate whether a person with a conductive hearing loss responds to the durational aspect of a stimulus in the same manner as a person with a sensorineural loss or a person with an auditory nerve lesion. Nor is it known whether the ability to perceive time is linearly related to the degree of hearing loss.

Knowledge of the ability to perceive durations might be extremely valuable in aural rehabilitation. Perhaps the hard-of-hearing person needs to be trained not only through increased intensity, especially at some frequencies, but also by having the duration of the acoustic stimuli extended.

Duration of speech sounds may also be a factor in the ability to read lips. Knowledge in this area could possibly improve lip reading training. It is possible, for example, that there might be a correlation between time perception and the ability to read lips.

It is felt that the next step toward a possible standardized test of time perception would be a decision regarding the psychophysical method to employ. Different types of interval contents should be studied to determine whether one or more types of stimuli has a more discriminatory nature. After such decisions have been made, standardization with normal subjects and comparative experiments with persons who have disorders of speech and hearing could then be accomplished.

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APPENDIX A

REPRODUCTION TIMES IN HUNDREDTHS OF SECONDS USED TO DETERMINE SUBJECT ACCEPTABILITY BY THE CRITERIA OF NO SIGNIFICANT DIFFERENCE BETWEEN MEANS AND A CORRELATION OF + .90

SUBJECT ONE

Frequency	Loudness	1 sec. I	1 sec. II	3 sec. I	3 sec. II	5 sec. I	5 sec. II	7 sec. I	7 sec. II	9 sec. I	9 sec. II
250 cps	40	1.27	1.34	3.73	2.70	4.32	4.20	4.24	6.25	6.46	5.74
	50	1.38	1.10	3.28	4.15	4.78	3.86	4.46	5.27	5.76	7.30
	60	1.00	0.99	2.48	3.57	4.94	4.28	5.11	5.40	6.19	5.20
	70	1.03	1.03	3.00	3.26	4.21	5.57	5.21	4.68	6.49	6.42
	80	1.06	0.92	3.11	2.44	4.37	4.50	5.87	5.33	5.26	6.91
500 cps	40	1.02	1.68	2.83	3.31	3.90	4.12	5.18	5.28	5.76	7.74
	50	1.00	0.92	2.88	3.47	4.99	4.27	5.11	5.80	5.62	6.26
	60	1.20	1.07	3.25	3.70	4.32	4.78	6.64	5.32	5.79	6.71
	70	0.74	1.10	3.18	3.11	4.45	4.06	6.17	5.53	6.77	8.07
	80	1.15	1.19	2.97	3.70	4.45	4.70	4.46	5.23	6.60	4.97
1000 cps	40	0.79	1.32	2.79	3.24	4.66	4.12	5.37	4.91	6.56	6.92
	50	1.15	1.09	3.17	3.57	4.01	4.98	6.52	5.64	6.44	5.98
	60	1.18	0.97	2.80	3.19	5.20	5.01	5.88	4.85	5.98	7.58
	70	1.10	1.02	3.35	2.78	3.63	4.03	4.94	5.83	5.86	6.66
	80	1.36	1.13	2.83	3.02	4.52	4.54	4.63	5.47	6.14	5.45
2000 cps	40	1.11	1.16	3.44	3.35	4.55	4.88	5.17	5.90	5.52	6.76
	50	1.41	1.30	2.81	3.09	4.04	5.80	6.65	5.23	5.43	6.54
	60	1.29	1.12	2.85	3.37	4.90	4.97	5.20	6.29	7.11	6.11
	70	1.12	1.69	2.33	3.26	4.60	4.78	5.43	6.63	6.02	6.45
	80	1.32	1.03	4.23	3.16	4.29	4.53	5.22	4.23	6.34	6.85
4000 cps	40	1.00	1.00	3.11	2.95	5.20	4.47	6.40	5.41	6.64	5.40
	50	1.10	1.20	3.08	2.45	3.99	4.88	5.56	5.39	5.95	6.45
	60	1.31	0.82	3.26	3.28	5.30	4.05	5.10	6.72	6.19	6.72
	70	1.63	1.39	3.14	3.18	4.58	4.37	5.34	5.15	5.44	5.68
	80	1.47	1.14	3.14	2.99	4.42	4.56	5.26	5.07	6.19	6.24

SUBJECT TWO

Frequency	Loudness	1 sec. I	1 sec. II	3 sec. I	3 sec. II	5 sec. I	5 sec. II	7 sec. I	7 sec. II	9 sec. I	9 sec. II
250 cps	40	1.27	1.75	3.52	3.06	5.11	4.95	5.18	6.89	6.45	6.48
	50	1.45	1.17	2.18	3.26	5.29	4.55	5.30	5.83	6.32	6.53
	60	0.99	1.24	3.06	3.35	3.95	3.76	4.84	5.46	6.56	6.90
	70	1.18	1.54	2.01	2.85	5.67	4.13	5.98	5.73	7.21	6.94
	80	1.15	1.67	3.74	3.73	4.25	4.47	5.21	4.49	7.26	7.43
500 cps	40	0.98	1.36	3.21	3.29	5.06	5.36	4.39	5.52	7.13	7.51
	50	1.51	1.93	2.46	3.57	4.24	5.13	5.40	6.10	6.60	5.26
	60	1.37	1.10	3.86	2.89	4.73	3.98	6.37	5.20	5.38	6.04
	70	1.19	1.32	3.15	2.38	4.15	4.80	5.32	5.45	6.23	5.94
	80	0.99	1.47	2.64	2.88	3.83	4.56	4.62	5.03	6.02	5.75
1000 cps	40	1.09	1.21	2.72	2.89	3.74	4.90	6.47	5.12	5.97	7.80
	50	1.04	0.99	3.41	2.91	4.89	4.44	6.15	5.83	5.55	5.36
	60	1.57	1.33	3.11	3.15	5.05	4.03	5.33	5.49	6.32	6.85
	70	1.12	1.44	3.55	3.94	3.79	4.28	5.35	4.85	6.63	6.37
	80	1.30	1.59	2.89	3.44	4.55	4.55	5.29	4.57	6.19	6.39
2000 cps	40	2.10	1.42	3.21	2.55	4.74	4.86	5.91	5.69	6.90	8.04
	50	1.21	1.50	2.63	2.77	3.97	4.40	5.88	4.43	6.26	8.06
	60	1.69	1.16	3.55	2.80	4.47	4.16	5.36	4.81	5.65	5.69
	70	1.24	1.20	2.59	3.22	4.17	4.02	5.30	5.78	5.86	5.54
	80	1.24	1.76	3.84	2.81	3.89	4.12	5.48	5.00	6.72	5.79
4000 cps	40	1.25	1.13	3.23	3.22	4.40	4.38	5.81	5.41	7.33	7.53
	50	1.38	1.21	2.26	3.35	5.20	4.46	5.77	5.40	5.89	5.20
	60	1.81	1.27	2.37	3.00	4.85	3.51	5.85	5.96	6.20	6.96
	70	1.26	1.48	3.01	2.51	4.67	3.51	5.27	6.30	6.64	6.28
	80	1.64	1.64	2.79	3.41	3.45	5.84	5.47	5.42	6.45	5.38

SUBJECT THREE

Frequency	Loudness	1 sec. I	1 sec. II	3 sec. I	3 sec. II	5 sec. I	5 sec. II	7 sec. I	7 sec. II	9 sec. I	9 sec. II
	40	1.13	1.28	3.11	3.36	5.97	5.05	6.78	7.42	10.03	8.20
	50	0.96	0.96	3.79	2.67	5.38	5.29	8.66	7.17	8.13	7.94
250 cps	60	1.28	1.05	3.34	3.68	5.17	5.25	6.50	7.37	7.98	9.01
	70	1.14	0.77	3.39	4.14	5.25	5.04	7.36	6.91	9.46	7.45
	80	1.03	0.72	2.96	3.44	5.34	5.44	7.63	6.37	9.64	8.87
	40	1.22	0.72	3.36	2.80	5.88	6.07	7.73	7.46	10.10	9.45
	50	1.14	1.14	3.60	3.17	5.07	4.78	6.22	7.10	7.66	8.65
500 cps	60	0.68	1.12	3.45	3.88	5.22	5.91	7.71	7.38	8.70	9.53
	70	0.99	1.19	2.78	4.63	5.66	5.88	7.00	7.64	8.69	9.48
	80	1.14	1.18	4.23	3.59	5.27	4.59	8.00	7.64	8.99	8.60
	40	1.05	1.45	3.74	3.66	6.02	5.65	7.16	8.29	8.53	7.97
	50	0.87	1.20	2.83	3.14	5.04	4.70	6.87	6.90	9.61	8.61
1000 cps	60	0.98	0.85	4.51	3.58	5.82	5.80	6.95	7.42	7.97	7.12
	70	1.39	0.86	2.98	3.57	5.70	4.68	6.53	7.53	7.70	8.86
	80	0.92	0.93	3.18	3.49	5.85	5.73	8.55	7.13	8.92	8.26
	40	1.22	1.04	4.20	4.24	5.15	5.58	7.28	7.48	8.96	9.20
	50	0.89	1.17	3.93	3.73	4.69	5.94	8.01	7.04	8.90	7.74
2000 cps	60	0.96	1.19	3.70	3.03	4.80	5.60	6.45	7.31	8.87	8.84
	70	0.87	1.10	3.21	3.37	5.73	5.66	7.57	7.18	9.72	9.18
	80	1.33	0.94	2.75	2.80	6.00	5.30	6.72	6.77	8.60	9.57
	40	1.16	1.05	4.00	3.68	5.35	5.78	7.66	7.18	10.07	9.21
	50	0.85	0.90	3.05	3.48	5.25	5.63	6.81	7.19	8.12	7.81
4000 cps	60	0.82	1.18	4.09	3.57	5.29	3.83	7.29	7.18	9.12	8.53
	70	0.93	0.90	3.85	3.35	4.33	5.70	6.60	6.05	9.49	9.00
	80	1.20	1.05	3.28	3.36	5.66	5.32	7.58	7.13	8.67	7.59

SUBJECT FOUR

Frequency	Phons	1 sec.		3 sec.		5 sec.		7 sec.		9 sec.	
		II	III	II	III	II	III	II	III	II	III
250 cps	40	1.80	2.31	2.76	4.04	4.47	5.22	6.90	6.56	7.82	8.76
	50	1.32	1.59	3.84	3.61	5.41	4.96	6.65	8.18	9.54	7.85
	60	1.35	1.75	3.71	3.36	5.22	6.10	6.15	6.36	7.67	8.93
	70	1.16	1.37	3.35	3.14	4.76	5.17	7.41	7.59	8.00	8.11
	80	1.65	1.41	3.40	3.04	4.91	6.43	5.20	4.14	8.46	9.67
500 cps	40	1.84	1.73	3.64	2.70	6.78	2.95	7.27	6.51	7.93	6.42
	50	1.50	1.35	3.17	3.97	4.68	4.32	7.32	6.19	7.88	5.03
	60	1.08	1.30	2.90	4.87	5.41	4.65	6.27	7.93	6.73	5.89
	70	1.11	1.97	3.44	4.45	5.09	5.59	6.78	7.46	7.00	6.88
	80	1.36	1.70	3.52	2.76	4.87	4.42	7.91	5.15	5.18	8.37
1000 cps	40	1.72	1.40	3.51	3.74	6.81	4.26	5.79	6.71	6.65	8.81
	50	1.64	1.47	5.06	4.44	4.84	5.84	4.86	4.93	8.03	7.20
	60	1.52	1.59	3.11	4.80	4.72	4.37	6.58	6.36	6.05	7.29
	70	1.28	1.28	3.80	3.20	4.97	3.51	6.71	6.34	8.74	8.76
	80	1.56	1.65	3.18	3.50	5.22	6.25	6.88	5.02	8.75	7.01
2000 cps	40	1.53	1.60	3.12	3.94	5.63	5.17	8.28	10.37	7.40	7.57
	50	1.34	2.00	3.69	3.86	5.20	4.14	4.48	5.84	6.90	8.62
	60	1.35	2.06	2.90	3.34	6.55	4.58	5.79	6.67	9.14	8.29
	70	1.50	2.59	3.40	3.34	5.04	4.30	7.90	6.77	5.31	8.34
	80	1.65	1.50	2.91	3.18	4.98	5.12	6.47	6.58	8.88	7.02
4000 cps	40	1.72	2.38	4.10	3.84	4.57	6.38	6.23	5.88	6.83	9.66
	50	1.32	2.15	3.38	4.16	5.28	5.78	6.18	5.90	7.64	8.37
	60	0.92	1.76	3.44	3.17	5.60	6.40	7.21	6.08	8.10	8.50
	70	1.63	1.97	3.15	3.67	7.11	4.83	6.85	6.91	5.58	7.90
	80	1.76	1.66	2.99	4.50	4.94	6.17	6.85	7.13	7.70	8.61

SUBJECT FIVE

Frequency	Phons	1 sec. I	1 sec. II	3 sec. I	3 sec. II	5 sec. I	5 sec. II	7 sec. I	7 sec. II	9 sec. I	9 sec. II
250 cps	40	1.26	1.42	3.21	3.39	6.41	4.88	9.57	7.56	9.85	10.27
	50	1.24	1.59	2.92	2.58	5.74	6.06	9.48	6.01	7.52	8.88
	60	0.97	0.98	4.44	3.64	5.05	4.29	6.76	6.70	8.28	9.47
	70	1.25	1.42	2.24	3.03	6.13	4.83	6.09	6.60	8.71	8.84
	80	1.28	1.13	3.22	4.19	5.39	4.79	6.88	5.25	6.63	7.37
500 cps	40	1.10	1.58	3.44	3.28	5.24	5.03	8.46	7.13	8.54	8.94
	50	1.13	0.86	3.25	3.05	5.47	5.42	6.77	7.05	7.67	9.07
	60	1.38	1.35	2.96	3.37	6.25	5.22	7.42	6.36	10.28	9.83
	70	1.12	1.61	3.08	2.84	6.02	6.07	6.89	6.26	7.71	8.53
	80	1.07	1.10	3.39	3.32	5.21	3.97	7.42	6.70	9.85	7.10
1000 cps	40	1.17	1.30	4.36	4.36	5.39	6.94	6.55	6.54	8.33	9.81
	50	0.99	1.18	3.71	2.82	5.04	5.96	9.85	5.95	6.10	7.23
	60	1.29	1.49	3.17	3.64	4.98	5.93	6.51	5.26	9.61	8.00
	70	1.48	1.22	2.73	3.03	4.97	5.56	6.19	7.04	8.02	8.35
	80	1.51	1.03	2.99	4.60	3.83	4.20	6.24	6.20	8.02	7.67
2000 cps	40	1.24	1.46	3.28	3.62	4.44	4.07	6.54	5.78	9.51	8.93
	50	1.42	1.03	3.48	3.18	4.26	6.33	7.77	6.63	7.62	7.84
	60	0.98	1.22	3.35	3.77	5.31	5.09	6.77	6.40	8.97	8.04
	70	1.56	1.09	3.19	3.06	5.30	6.10	7.53	6.34	7.57	6.77
	80	1.24	1.46	2.87	2.75	3.61	4.53	8.33	6.17	8.38	8.48
4000 cps	40	1.82	1.72	3.43	4.82	4.65	6.52	8.98	8.25	7.64	9.92
	50	1.77	1.36	4.70	4.44	6.58	5.83	9.12	7.31	7.84	7.98
	60	1.12	1.30	4.30	3.80	6.45	4.45	7.20	6.97	8.53	8.93
	70	1.54	1.18	3.31	4.17	5.46	4.89	5.77	6.35	8.36	7.12
	80	1.62	1.14	2.71	4.65	4.73	5.37	7.17	7.36	8.38	8.45

APPENDIX B

RAW DATA USED IN THE ANALYSIS OF VARIANCE: REPRODUCTION TIME (IN $\frac{\Delta T}{T}$) AVERAGED OVER THE LAST TWO EXPERIMENTAL SESSIONS FOR EACH SUBJECT

ONE SECOND

		40 Phons	50 Phons	60 Phons	70 Phons	80 Phons
250 cps	S1	0.30	0.23	-0.01	0.03	-0.02
	S2	0.50	0.31	0.12	0.35	0.41
	S3	0.20	-0.04	0.16	-0.04	-0.13
	S4	1.05	0.46	0.58	0.26	0.53
	S5	0.34	0.41	-0.01	0.34	0.20
500 cps	S1	0.35	-0.04	0.14	-0.09	0.17
	S2	0.16	0.72	0.23	0.26	0.23
	S3	-0.03	0.13	-0.10	0.08	0.15
	S4	0.78	0.42	0.18	0.54	0.53
	S5	0.33	-0.01	0.36	0.36	0.08
1000 cps	S1	0.06	0.12	0.08	0.06	0.24
	S2	0.15	0.00	0.45	0.27	0.44
	S3	0.25	0.04	-0.08	0.12	-0.08
	S4	0.56	0.54	0.56	0.27	0.60
	S5	0.24	0.08	0.39	0.34	0.27
2000 cps	S1	0.13	0.36	0.20	0.40	0.18
	S2	0.75	0.34	0.42	0.22	0.50
	S3	0.12	0.03	0.07	-0.02	0.14
	S4	0.56	0.65	0.70	1.04	0.58
	S5	0.34	0.22	0.10	0.32	0.35
4000 cps	S1	-0.01	0.14	0.06	0.50	0.30
	S2	0.18	0.28	0.37	0.37	0.64
	S3	0.10	-0.13	0.00	-0.09	0.12
	S4	1.03	0.72	0.34	0.81	0.71
	S5	0.75	0.56	0.20	0.36	0.38

THREE SECONDS

		40 Phons	50 Phons	60 Phons	70 Phons	80 Phons
250 cps	S1	0.07	0.24	0.01	0.04	-0.08
	S2	0.09	-0.10	0.07	-0.19	0.24
	S3	0.07	0.08	0.17	0.25	0.06
	S4	0.13	0.24	0.18	0.08	0.07
	S5	0.10	-0.08	0.35	-0.12	0.23
500 cps	S1	0.02	0.06	0.15	0.04	0.11
	S2	0.08	0.00	0.12	-0.08	-0.08
	S3	0.02	0.12	0.22	0.23	0.30
	S4	0.06	0.19	0.30	0.30	0.04
	S5	0.12	0.05	0.05	-0.02	0.12
1000 cps	S1	0.00	0.12	-0.00	0.02	-0.02
	S2	-0.07	0.05	0.04	0.24	0.05
	S3	0.23	-0.01	0.35	0.09	0.11
	S4	0.20	0.58	0.32	0.16	0.11
	S5	0.45	0.08	0.13	-0.04	0.26
2000 cps	S1	0.13	-0.02	0.03	-0.07	0.23
	S2	-0.04	-0.10	0.05	-0.03	0.11
	S3	0.40	0.27	0.12	0.09	-0.08
	S4	0.17	0.25	0.04	0.12	0.01
	S5	0.15	0.11	0.18	0.04	-0.06
4000 cps	S1	0.01	-0.08	0.09	0.05	0.02
	S2	0.07	-0.07	-0.11	-0.08	0.03
	S3	0.28	0.09	0.28	0.20	0.10
	S4	0.32	0.25	0.10	0.13	0.24
	S5	0.38	0.52	0.34	0.24	0.22

FIVE SECONDS

		40 Phons	50 Phons	60 Phons	70 Phons	80 Phons
250 cps	S1	-0.15	-0.14	-0.08	-0.02	-0.11
	S2	0.00	-0.02	-0.23	-0.02	-0.13
	S3	0.10	0.06	0.04	0.03	0.08
	S4	-0.03	0.03	0.13	-0.01	0.13
	S5	0.13	0.18	-0.07	0.09	0.02
500 cps	S1	-0.20	-0.07	-0.09	-0.15	-0.09
	S2	0.04	-0.07	-0.13	-0.11	-0.16
	S3	0.20	-0.01	0.11	0.15	-0.02
	S4	-0.03	-0.10	0.00	0.06	-0.07
	S5	0.03	0.09	0.04	0.20	-0.08
1000 cps	S1	-0.12	-0.10	0.02	-0.24	-0.10
	S2	-0.14	-0.07	-0.09	-0.20	-0.09
	S3	0.16	-0.03	0.16	0.04	0.16
	S4	0.10	0.06	-0.09	-0.15	0.14
	S5	0.23	0.10	0.09	0.05	-0.20
2000 cps	S1	-0.06	-0.02	-0.01	-0.06	-0.12
	S2	-0.04	-0.16	-0.14	-0.18	-0.20
	S3	0.07	0.06	0.04	0.14	0.13
	S4	0.08	-0.07	0.11	-0.07	0.00
	S5	-0.15	0.06	0.04	0.14	-0.19
4000 cps	S1	-0.04	-0.11	-0.07	-0.10	-0.10
	S2	-0.12	-0.04	-0.16	-0.18	-0.07
	S3	0.11	0.09	-0.09	0.00	0.10
	S4	0.09	0.10	0.20	0.19	0.11
	S5	0.12	0.24	0.09	0.03	0.01

SEVEN SECONDS

		40 Phons	50 Phons	60 Phons	70 Phons	80 Phons
250 cps	S1	-0.25	-0.30	-0.25	-0.29	-0.20
	S2	-0.14	-0.21	-0.26	-0.16	-0.27
	S3	0.01	0.13	-0.01	0.02	-0.00
	S4	-0.26	0.06	-0.11	0.07	-0.33
	S5	0.22	0.11	-0.04	-0.09	-0.13
500 cps	S1	-0.25	-0.22	-0.15	-0.16	-0.31
	S2	-0.29	-0.18	-0.17	-0.23	-0.31
	S3	0.09	-0.05	0.08	0.05	0.11
	S4	-0.02	-0.04	0.01	0.02	-0.07
	S5	0.11	-0.01	-0.02	-0.06	0.01
1000 cps	S1	-0.26	-0.13	-0.23	-0.23	-0.28
	S2	-0.17	-0.15	-0.23	-0.27	-0.30
	S3	0.18	-0.02	0.03	0.01	0.12
	S4	-0.11	-0.30	-0.08	-0.07	-0.15
	S5	-0.06	0.13	-0.16	-0.06	-0.11
2000 cps	S1	-0.21	-0.15	-0.18	-0.15	-0.32
	S2	-0.17	-0.26	-0.27	-0.21	-0.25
	S3	0.05	0.07	-0.02	0.04	-0.04
	S4	0.33	-0.26	-0.11	0.05	-0.07
	S5	-0.12	0.03	-0.06	-0.01	0.04
4000 cps	S1	-0.16	-0.22	-0.16	-0.25	-0.26
	S2	-0.20	-0.20	-0.16	-0.18	-0.22
	S3	0.06	0.00	0.03	-0.10	0.05
	S4	-0.14	-0.14	-0.05	-0.02	-0.00
	S5	0.23	0.17	0.01	-0.13	0.04

NINE SECONDS

		40 Phons	50 Phons	60 Phons	70 Phons	80 Phons
	S1	-0.32	-0.27	-0.37	-0.28	-0.32
	S2	-0.28	-0.29	-0.25	-0.21	-0.19
250 cps	S3	0.01	-0.11	-0.06	-0.06	0.03
	S4	-0.08	-0.07	-0.08	-0.11	0.00
	S5	-0.02	-0.09	-0.01	-0.02	-0.22
	S1	-0.25	-0.34	-0.30	-0.18	-0.36
	S2	-0.19	-0.34	-0.36	-0.32	-0.35
500 cps	S3	0.08	-0.09	0.05	0.01	-0.02
	S4	-0.21	-0.28	-0.30	-0.13	-0.25
	S5	-0.03	-0.07	0.12	-0.10	-0.06
	S1	-0.25	-0.31	-0.25	-0.30	-0.36
	S2	-0.24	-0.39	-0.27	-0.28	-0.30
1000 cps	S3	-0.08	0.01	-0.16	-0.08	-0.04
	S4	-0.14	-0.15	-0.26	-0.03	-0.12
	S5	0.01	-0.26	-0.02	-0.09	-0.13
	S1	-0.32	-0.33	-0.26	-0.31	-0.27
	S2	-0.17	-0.20	-0.37	-0.37	-0.30
2000 cps	S3	0.01	-0.08	-0.02	0.05	0.01
	S4	-0.17	-0.14	-0.03	-0.24	-0.12
	S5	0.02	-0.14	-0.05	-0.20	-0.06
	S1	-0.33	-0.31	-0.28	-0.38	-0.31
	S2	-0.17	-0.38	-0.27	-0.28	-0.34
4000 cps	S3	0.07	-0.12	-0.02	0.03	-0.10
	S4	-0.08	-0.11	-0.08	-0.25	-0.09
	S5	-0.02	-0.12	-0.03	-0.14	-0.06

APPENDIX C

RAW SCORES (IN $\frac{\Delta T}{T}$) USED TO DETERMINE WHETHER JUDGMENTS IN THE FIRST HALF OF AN EXPERIMENTAL SESSION DIFFERED FROM JUDGMENTS IN THE SECOND HALF

First Half	Second Half	First Half	Second Half	First Half	Second Half
		Subject One			
0.07285	-0.32036	-0.26534	-0.20774	-0.23111	-0.01667
0.10927	-0.10333	-0.10956	0.13000	-0.14770	-0.30367
-0.42350	0.68000	-0.18889	-0.00599	0.03000	-0.08911
-0.17928	-0.21857	0.09603	0.02000	-0.10714	-0.44778
-0.40133	0.30000	-0.22825	0.37624	-0.24714	-0.18000
-0.19323	-0.17143	-0.09581	-0.16595	-0.10143	-0.27468
0.03322	-0.12774	-0.36959	0.32000	-0.24722	0.08911
-0.23973	-0.10180	-0.00798	-0.23051	-0.01980	-0.22924
-0.25333	-0.28428	0.67327	-0.16168	-0.27253	-0.18333
-0.03000	-0.23748	0.00000	0.19000	0.11400	-0.15778
-0.00993	0.16000	-0.14000	-0.25753	0.23333	0.03000
-0.06882	-0.28254	-0.33482	-0.02400	0.02318	-0.15714
-0.36293	0.00667	-0.28333	-0.30615	-0.02789	0.10891
-0.19772	0.14851	0.07000	0.09333	0.37874	-0.10299
0.07947	-0.25286	0.00000	-0.39398	-0.08911	0.19000
-0.04781	0.15282	-0.19561	-0.17600	-0.22954	-0.39444
-0.25605	-0.06375	0.18812	-0.14400	-0.25444	-0.08982
-0.18937	0.09000	0.08306	-0.29656	-0.09381	0.19000
-0.19124	-0.03863	-0.22857	-0.33047	-0.07333	-0.04400
-0.30667	-0.22890	0.05648	0.14000	0.08911	0.34000
0.11960	-0.24464	-0.24108	0.05333		
		Subject Two			
-0.06645	0.22772	-0.09182	-0.01571	0.47000	0.11296
-0.15842	-0.14735	0.04651	-0.29940	-0.21571	-0.22974
-0.07901	-0.21030	-0.04319	-0.35857	-0.28000	0.67000
-0.23077	0.06986	-0.14571	-0.08982	-0.04000	0.20000
0.16000	-0.10256	-0.16333	-0.29940	0.18605	-0.28143
-0.17729	0.14667	0.24333	-0.18260	-0.02196	-0.26857
-0.12749	-0.03667	-0.40444	-0.16966	0.06977	-0.22667
-0.16611	-0.35452	0.06977	-0.10978	-0.12351	0.13667
0.19802	-0.29301	-0.05000	0.48515	-0.17429	-0.13333
0.17000	-0.25714	-0.24950	0.93000	0.36000	-0.09000
-0.11133	-0.38444	-0.30714	-0.19400	-0.29079	-0.22714
0.42000	-0.17600	-0.32814	-0.34621	-0.01980	-0.00332
0.11881	-0.22111	-0.36707	0.09667	-0.40156	0.10000
-0.11377	0.11667	-0.10345	-.52475	-0.28571	-0.20930
-0.36182	0.02000	-0.22254	-0.42222	0.76000	0.32000
-0.31384	0.42574	-0.02994	0.16800	-0.34000	0.73267
0.21000	-0.36714	-0.03322	-0.23973	-0.22571	-0.27364
-0.16833	0.08306	0.64000	-0.16833	-0.16556	-0.01000
-0.18714	-0.03987	-.02191	-0.06667	-0.10667	0.30897
-0.07973	-0.23418	-0.20717	0.25743	-0.12857	0.59000
-0.41491	0.46535	-0.19600	0.33000		

First Half	Second Half	First Half	Second Half	First Half	Second Half
		Subject Three			
0.21192	-0.01669	-0.13695	0.09456	-0.11444	0.22667
0.40397	0.05333	0.15139	-0.07000	-0.04591	-0.03782
-0.00111	-0.28000	-0.11778	-0.06188	-0.23000	0.12871
0.12550	0.01857	-0.07285	-0.14000	-.06000	-0.04444
0.02106	0.17000	0.02425	-0.10891	0.02429	0.18000
-0.23705	-.01429	0.05788	0.07725	0.04429	0.02003
0.53821	0.13772	-0.00111	0.45000	0.02450	0.17822
0.06215	0.08583	0.11776	-0.01225	0.03960	0.28904
-0.05222	-0.16945	0.08911	0.00798	-0.13904	0.16000
-0.15000	-0.08870	0.05000	0.18000	0.00800	-0.20889
0.11258	0.18800	0.05000	-0.01226	0.19667	-0.06000
0.00843	0.02113	-0.04227	0.12600	0.23510	0.06857
-0.08990	0.16333	-0.13222	0.06152	0.11155	0.17822
-0.01849	0.02970	0.12000	0.19000	-0.11296	0.11628
0.37086	0.00571	0.15768	-0.03009	-0.28713	0.04667
0.17729	0.05316	-0.06587	-0.21400	0.05589	-0.08222
0.08677	-0.08566	-0.10891	0.05000	0.05889	0.06188
0.14286	0.20000	0.11960	0.18768	0.14371	0.22667
0.17131	0.02718	0.05286	-0.01144	0.19000	0.13200
-0.15667	0.02861	0.11296	0.05000	-0.04950	0.28000
0.00664	0.06724	0.05278	-0.06667		
		Subject Four			
0.01712	-0.00667	0.41000	0.58416	0.50000	-0.12320
-0.04440	0.35000	-0.23556	-0.10000	0.98990	-0.06000
0.06571	0.45545	-0.26429	0.12000	0.16335	-0.41000
0.81443	-0.04222	0.27600	0.00997	-0.01195	-0.02882
-0.08306	-0.09143	-0.17635	0.02988	0.47508	-0.16571
-0.11776	-0.13944	0.02196	-0.01427	0.98020	0.06312
-0.12971	-0.07333	-0.06419	0.07214	1.59000	-0.12774
0.70000	-0.09429	-0.07133	1.06000	-0.02667	-0.19090
-0.20089	-0.04006	0.11355	-0.22087	0.16279	0.05316
-0.07889	0.19934	0.38667	0.06000	0.26733	0.71287
0.04319	-0.07000	-0.14970	-0.15835	-0.44111	0.23154
0.03984	0.28000	-0.22111	0.15139	0.59000	0.28239
-0.03593	0.10596	0.31333	0.49502	0.08429	1.31000
-0.13143	-0.30080	-0.16075	-0.11698	0.59000	1.35644
0.21756	0.12963	-0.34483	-0.09989	-0.05556	0.97000
0.03194	1.12871	0.24750	-0.07186	-0.14000	-0.09143
0.40000	0.28343	0.65000	0.47721	0.16690	-0.08583
-0.02111	0.46865	0.76000	-0.28825	-0.03147	0.32333
0.21927	0.28000	-0.04714	0.60000	0.66000	0.24252
-0.07000	0.07206	-0.28388	-0.29772	-0.16000	0.37000
0.11333	0.62333	-0.40857	0.34219		

First Half	Second Half	First Half	Second Half	First Half	Second Half
		Subject Five			
0.04993	0.05339	0.13000	0.44554	0.46000	-0.20977
-0.06215	-0.14000	-0.05222	0.09333	0.19192	-0.11857
-0.10571	0.16832	-0.04286	0.21333	0.18725	0.00600
0.01031	-0.12889	0.30400	0.39203	0.20717	-0.07428
0.10299	-0.04286	0.26347	-0.03785	-0.06312	-0.05286
-0.20758	0.07968	-0.09581	-0.09415	0.01980	0.00664
-0.01552	-0.24778	0.07846	0.10100	0.09000	0.18363
0.10000	0.00571	0.01712	0.22000	-0.14111	-0.11210
-0.19756	-0.06438	0.20916	-0.05882	0.52824	0.26246
-0.10667	-0.14286	0.48000	-0.08333	0.21792	0.56436
0.00664	-0.11333	0.38523	0.04280	0.00778	0.07186
-0.02789	0.60667	-0.14778	0.16135	0.59000	0.05648
-0.02395	0.24834	0.20667	0.54485	-0.05714	0.42000
-0.00429	0.10757	-0.00998	0.00571	0.49000	0.70297
-0.14371	-0.09402	0.09344	-0.01887	-0.00778	0.61000
-0.18762	0.34653	-0.16168	0.04192	0.22000	-0.24857
0.30000	-0.04391	0.03000	-0.17664	-0.14265	0.01597
0.09000	-0.06271	0.30000	-0.00887	-0.09299	0.01667
0.38538	-0.11000	-0.08571	0.21333	0.14000	0.44850
-0.21111	-0.18293	-0.11555	-0.15242	0.17857	0.42000
0.02000	0.12333	-0.25000	0.12625		