A STUDY OF FATIGUE AND DISORGANIZATION OF PERFORMANCE IN RELATION TO THE PHENOMENOLOGICAL VARIABLES OF DURATION, CHANGE AND MOVEMENT

Thesis for the Degree of Ph. D.

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Thomas Morgan Nelson

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This is to certify that the

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A STUDY OF FATIGUE AND DISORGANIZATION OF PERFORMANCE IN RELATION TO THE PHENOMENOLOGICAL VARIABLES OF DURATION, CHANGE AND MOVEMENT

by

Thomas Morgan Nelson

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
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Department of Psychology

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A B S T R A C T.

Abstract

The thesis is divided into two parts. Part 1 dealt with problems involving phenomenal duration, phenomenal change, and phenomenal movement. All three variables were discussed and explicitly defined. Phenomenal duration received the most extended treatment since it is "time bound" in ordinary thinking. The author attempted to disassociate phenomenal duration not only from concepts of time but also from non-phenomenal concepts of duration. Operational equivalents of the acceptable phenomenal definitions were given. A fairly extensive review of prior experimentation relating phenomenal duration and phenomenal change, and, phenomenal duration and phenomenal movement was made. On the basis of the definitions and empirical results obtained by the prior investigators, 19 studies were undertaken.

The experimental equipment used was designed not only to produce the requisite phenomenal variables but also to measure and control them. All studies employed psycho-physical methods. The number of subjects used varied between 1 and 18 per study. The results of the experimentation confirmed a hypothesis stating that "phenomenal duration is a function of phenomenal change" and disconfirmed the second which stated that "phenomenal duration is a function of phenomenal movement." Related facets of the study were also discussed, e.g. change and movement control, subjective reports concerning procedure, and success of the methodology. A theoretical

statement termed the Theory of Phenomenal Duration was issued. The theory states that "the experience of duration is a predicate of phenomenal change but not phenomenal continuity" and that "phenomenal continuities are durationless although extended in phenomenal space while phenomenal changes are both durations and extended in phenomenal space." This theory was applied to previous "time perception" work of several types.

Part 2 dealt with the problems involving variables of phenomenal change, phenomenal duration, fatigue, and task performance. The concept of fatigue was discussed and Bartley and Chutes' definition accepted. This definition makes it mandatory to investigate tiredness and separates fatigue from what is called impairment (physiological fatigue) and work productivity (overt behavior decrement). The literature published since 1947 relating phenomenal variables to fatigue, and reaction time to fatigue was reviewed. The studies reviewed indicated that little was known concerning the relationship. The study described was designed to investigate the relationship between ambient phenomenal change and ambient phenomenal duration and fatigue, and to test whether fatigue as defined had an effect upon reaction time.

Three subjects were given nine individual trials each. Each trial required as rapid motor or verbal responses as they were able to give when visual targets embedded in the ambient phenomenal conditions appeared. The subjects worked until they were "too tired to go on." The first hypothesis stating "fatigue will develop as a function of ambient change and duration" was confirmed. The experimental outcome, however, was not simple. It was found that when the ambient phenomenal variables were of "rapid change" and "long duration" that the subjects performed differently than when the ambient phenomenal condition was a "slow change" and "short duration". In the initial trials the "rapid change-long duration" variables produced fatigue most slowly, in the later trials more quickly. The slow change and short duration ambient condition functioned somewhat differently. The initial trial resulted in rapid fatigue, the second in slow fatigue, and the third showed large individual differences between subjects. The 2nd hypothesis stating that "the emergence of fatigue will detract from the performance of a reaction time task" was also confirmed. Working under conditions of fatigue gave rise to a large increase and variability in reaction time. The onset of fatigue could not be predicted from the reaction time measures however. A definition of disorganization was given.

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FOREWORD

A casual glance at the table of contents shows that the dissertation is divided into two parts. In a sense, two dissertations will be presented, with the second being built upon the empirical relationships discovered in the first. In Part 1, we will deal with the question "What is the relationship between phenomenal changes, movements and phenomenal durations?" In Part 2, we will ask "What is the relation between the ambient conditions of phenomenal duration and the emergence of tiredness (fatigue), and, "What happens to performance when fatigue exists?"

Both Part 1 and Part 2 have the same general structural plan. Thus, the initial chapters of each part deal with problems of definition, the second chapters contain reviews of the literature, the third presentations of problems, hypotheses, experimentations and results, the fourth discussions of results and conclusions, and the last summaries of results. The only exceptions to this rule occur in Part 1. Here the first chapter is enlarged by a short discussion of meaning and the fourth by presentation and consideration of a theory to account for the empirical findings.

The word "phenomenal" constantly occurs as a prefix for the variables. This may be disturbing either because one is uncertain of the meaning of the appended term or perhaps because one actually identifies it with a particular philosophical outlook. If this happens, the term has been an unfortunate selection. Nonetheless, I believe that the term "phenomenal" can do us good service if the meaning is carefully denoted. It will be well, then, to spend a moment with this term now since it will not be discussed formally anywhere else.

Immanuel Kant was probably the most influential philosopher to give the term a fundamental place within a philosophical system. He is of far less direct importance for psychology than is Edmund Husserl, however. It was Husserl who first distinguished an entire philosophical outlook as a "phänomenalogie," and hence Husserl whom one must consider most seriously. Initially, Husserl conceived the task of the phenomenalogist to be that of providing a descriptive analysis of conscious processes. In this early stage the phenomenological problem was not markedly different from that of introspective psychology. By stages, however, philosophical phenomenology underwent redefinition and in the end existed solely as a method of probing into the "intrinsic nature" of subjective processes. Husserl, in these later stages of theory, pointedly divorced phenomenology from actual individual experiences. The phenomenological observer endeavored to apprehend what was believed to be the fundamental character of the world. Ordinary "worldly" experience was treated as being but a reflexive consequence of some nucleus of subjectivity. The extent to which phenomenology was at this point alienated from empirical matters is expressed in

Husserl's assertion that:

> "What we demand lies along another line, the whole world as placed within a nature setting and presented in experience as real, taken completely 'free from all theory,' just as it is in reality experienced, and made manifest in and through the linkings of experience, has now no validity for us, it must be set in brackets, untested indeed but also uncontested."[1]

Programs such as the above, one might call "philosophical phenomenology" so as to distinguish them from "psychological" or "empirical phenomenology."

It must be emphasized that the problems and experimental approach outlined in this dissertation have nothing particularly to do with Philosophical Phenomenology. On the other hand, they are integral parts of Psychological Phenomenology. Concerning the program of Psychological Phenomenology, the following may be said.

1. Psychological phenomenological problems fit the following criteria. They are problems that concern only what the subject personally observes concerning some aspect of the world. This means that they are problems that will yield data that can be expressed in some form of the personal idiom, i.e. "I saw it change," "The first interval had a longer duration than the last for me," "I experience this to be moving more rapidly than that," "I am so tired that I can not go on."

2. A psychological phenomenological experimental approach emphasizes that the experimenter is pursuing a "subject centered" and not an "experimenter centered" methodology. This means that the subject and not the experimenter is doing the

1. E. Husserl, Ideas: An Introduction to Pure Phenomenology. (New York: The MacMillan Co., 1931) p. III.

observing. The experimenter is present in the laboratory merely to direct the subject to phenomena, to control and alter the experimental situation for the observer, and to record his personal responses.

3. The self-contained purpose of psychological phenomenology is the development of what Peterman calls "non-constructional theory." Non-constructional theory means a theoretical interpretation of the data which proceeds by establishing functional dependencies between phenomenal facts to which no ontological parallels are directly attributed. This interpretation proceeds by first determining the data, exactly and painstakingly, and then by recognizing the functional tendencies within the data from knowledge, as an experimenter, of the relationships within the experimental conditions.

The necessity for incorporating some such outlook into contemporary psychology seems patient to me. Others, of course, might doubt the validity of this judgment. While this is not a place in which we can consider any objection at length, let me briefly answer one criticism made. This criticism is epitomized by the question, "Why bother about such matters?"

Anyone asking such a question evidently doubts that phenomenal problems are of importance. But, unless one wants to divorce psychology from all other well established scientific points of reference, the point is poorly taken. Considering, as examples, only the phenomenal variables treated in this thesis, one can make obvious the insufficiencies in such an outlook. Does not the problem of change, according to Alfred North Whitehead, underlie two of the most important advances made in modern science, the doctrine of the conservation of energy and the doctrine of evolution? Is not the nature of time one of the most vexsome problems of our age, and do not Albert Einstein, Bertrand Russell, and P.W. Bridgeman claim that the individual is the ultimate referent? The remainder, those who disclaim to see any merit in scientific psychology, and there are still psychologists who hold such views, are trapped by the question, "Is it true that fatigue incapacitates every last one of us sometime during the course of each and every day?" Only a mystic can successfully deny the relevance of phenomenal experience.

The contemporary psychologist often finds his chief delight in the manufacture of attitudes, personalities, "need systems," and responses. To a disturbing degree, we are becoming exclusively preoccupied with "self defined" problems and with contrivances extraneous to our fundamental purposes for existence. One finds no dearth of contemporary literature concerning "ego blocking," "latent anxiety", "obstacle dominance", Rorschach responses, "authoritarian personalities", "drive discrimination", factored traits, etc. But, oddly enough, increasingly fewer investigations into <u>factual problems</u> such as duration, change and fatigue. Even worse, when the attention of psychology is turned toward factual problems it too often terminates in an operationism that defines the problems out of existence. Hence, I do not think one should stop with just successfully defending the phenomenal position. I think the alternatives should be explored. I think that it should be made entirely clear that the long-standing problems of mankind are being increasingly shunted to the side for games invented by some psychologists. We should become fully aware that we are, as a discipline, becoming estranged from "mother nature", from the world of concrete fact. We should recognize that we are in certain danger of progressing, by one of a number of paths, to a subject matter purely conceptual in character, and that, unless something is done, we will continue to address ourselves more and more to a subject matter esoteric from all other established points of reference. We have to discern that somehow, and however painfully, psychology must deal with basic problems. We have to somehow correct the peculiar aniseikonia which has afflicted contemporary psychology and which is perhaps responsible for our being in the midst of one of the dullest stages of psychological thought since the establishment of the first laboratory.

ACKNOWLEDGEMENT

I should like to acknowledge the help given me during the course of this research. I wish to express especial appreciation to Dr. S. Howard Bartley. His patience and confidence lasted over many years. For him, academic freedom is more than a verbal concept.

I would also like to express appreciation for the services of the other committee members, Dr. M. Ray Denny, Dr. Alfred Dietze, and Dr. Lewis Zerby. They and Dr. Donald Johnson, who served as a committee member up to the time of his sabbatical leave, devoted many hours to a project that was not of central concern to them. I wish also to mention my indebtedness to my three paid subjects. Mr. David Birdsong observed 125 hours, Miss Virginia Dudley 89 hours, and Mr. Kenneth Rouse 30 hours on tasks that were in fact fatiguing and disagreeable. Nor should I conclude without acknowledging the rapid and careful graph work of Mr. Malcome Cranson, and the general assistance given at every turn by Joyce Nelson and Mr. Charles Bourassa, the typing assistance of both Mrs. Victor Armitage and Miss Gloria Cheek.

VITA

Thomas M. Nelson

candidate for the degree

of

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Final Examination

March 10, 1958, 3 P.M., Room 15, Psychology Building

Dissertation

A STUDY OF FATIGUE AND DISORGANIZATION OF PERFORMANCE IN RELATION TO THE PHENOMENOLOGICAL VARIABLES OF DURATION, CHANGE AND MOVEMENT

Outline of Studies

Major Subject: Experimental Psychology
Minor Subject: Philosophy

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Born: August 13, 1924, Negaunee Michigan

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TABLE OF CONTENTS

TABLES

LIST OF FIGURES

PART I

Phenomenal Duration, Change, and Movement

"Further in obedience to the principle of comprising within nature the whole terminus of sense-awareness, simultaneity must not be conceived as an irrelevant mental concept for immediate discernment a certain whole, here called a 'duration'; thus a duration is a definite natural entity."

"Durations have all the reality that nature has, though what that may be we need not now determine. The measurableness of time is derivative from the properties of durations. So also is the serial character of time." (A. N. Whitehead, _The Concept of Nature_, Ann Arbor, Univ. of Mich. Press, 1957, pp. 53, 55).

"A perceived duration or temporal pattern is a psychological entity that is inferred from and defined by certain operations of introspective report, which adequately imply the differentiation of the perception. This "behavioral" inversion of the point of view toward experience makes the perception, not a private immediate experience, but a psychological _construct_ which (in a rat or a person or myself) is just as public as is any other convincing inference from data." (E.G. Boring, "Temporal Perception and Operationism," _Amer. J. Psychol._, XLVIII, 1936, p. 521.)

CHAPTER I

The Phenomenal Variables

INTRODUCTION

This paper concerns "phenomenal duration." For the purpose of discussion prior to a formal operational definition, "phenomenal duration" can be considered as the "For-me endurance of an externally localized event."

The approach taken to the problem of phenomenal duration is experimental and the general aim of the experiments is two-fold. One, the experiments aim to discover, or if you will, invent, phenomenal conditions under which phenomenal duration can be shortened and lengthened, relative to the clock time dimension. Two, the experiments aim to measure the relative extent of any lengthening or shortening of phenomenal duration achieved by manipulation of the experimental variables.

The primary variables selected for experimental manipulation are those of phenomenal change and phenomenal movement. The phenomenal change and movement variables themselves are of numerous sorts, as the later sections dealing with the experiments themselves will show.[1] These variables will be expressed by a physical measurement as well.

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1. The author in no way implies that certain other non-experiential variables, e.g. physiological, social, physical, or personal do not enter in any given situation. Phenomenal change and movement are simply the variables selected for study.

The general implications of the terms duration, change, and movement will be discussed in chapters three, four, and five, and the terms phenomenal change, phenomenal duration, and phenomenal movement will be formally denoted in the same chapters. Before doing this, however, there will be a digression in chapter two in the form of a discussion of meaning. This has been done because in American psychological circles all variables referring to experience are objects of suspicion.

MEANING AND EMPIRICAL MEANING CRITERION

Any term may have cognitive meaning functions, such as factual, purely formal, and logical-arithmetical; and non-cognitive meaning functions, such as the pictorial, affective, and directive. Within this paper the discussion of meaning can be restricted to consideration of the question of what would constitute the empirical or factual functions for terms referring to experience, since the aim of this dissertation is to clarify the terms phenomenal duration, phenomenal movement, and phenomenal change, experimentally. [2]

Meaning of Experimental Terms: The current conceptions and criterion of meaning within philosophy of science in many respects vary from one school of philosophic analysis to another. Nevertheless, it is generally agreed that one must be able in some way to recognize the term asserted on an empirical level. If this cannot be done, the verbal

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2. Attempts at clarification of meaning are often suspected of being designed and employed by psychologists seeking to circumvent difficult problems, e.g., experience. At other times attempts at clarification are suspected to be part and parcel of a "behavioristic" program, with the result that little importance is attached to the results beyond this point. Although the method of clarification is almost certain to restrict the scope of application for the term, when this resulting scope is compared to the breadth of ordinary common sense usage, and even though many logical epistomologists have marked sympathy for "behavioristic" type systems of psychology, neither need be the case.

expression is said to lack a factual meaning because it does not affirm anything widely intelligible. Hence, the question of the meaningfulness of scientific terms rests in the question of whether there is a factual referent. [3]

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3. Moritz Schlick, for example, says, "Thus, whenever we ask about a sentence, 'What does it mean?', what we expect is instruction as to the circumstances in which the sentence is to be used; we want a description of the conditions under which the sentence will form a true proposition, and of those which will make it false. The meaning of a word or a combination of words is, in this way, determined by a set of rules which regulate their use and which, following Wittgenstein, we may call the rules of their grammar, taking this word in its widest sense." "Meaning and Verification," Readings in Philosophical Analysis, ed. by Herbert Feigl and Wilfrid Sellars (New York: Appleton-Century-Crofts Inc., 1949), pp. 147-148.

Rudolf Carnap, somewhat in contrast, suggests that meaning resides basically in the formulation of observation sentences. He says regarding this, "A first attempt at a more detailed explanation of the thesis of verifiability has been made by Schlick in his reply to Lewis' criticisms. Since 'verifiability' means 'possibility of verification' we have to answer two questions: 1) what is meant in this connection by 'possibility'? and 2) what is meant by 'verification'? Schlick- in his explanation of 'verifiability'- answers the first question, but not the second one. In his answer to the question; what is meant by 'verifiability of a sentence S'c he substitutes the fact described by S for the process of verifying S. Thus, he thinks e.g. that the sentence S_1 "Rivers flow up-hill", is verifiable, because it is logically possible that rivers flow up-hill. I agree with him that this fact is logically possible and that the sentence S_1 mentioned above is verifiable- or, rather, confirmable, as we prefer to say for reasons to be explained soon. But I think his reasoning which leads to this result is not quite correct. S_1 is confirmable, not because of the logical possibility of the fact described in S_1, but because of the physical possibility of the process of confirmation; it is possible to test and to confirm S_1 (or its negation) by observations of rivers with the help of survey instruments." Testability and Meaning (New Haven, Conn. Yale University Graduate Philosophy Club, 1950), p. 423.

C. Lewis offers the following; "The requirement of empirical meaning is at bottom nothing more than the obvious one that the terms we use should posses denotation. As this requirement is interpreted by pragmatists and positivists, THE

Any further specification, such as a requirement that the descriptions must be expressed as "purely physical processes", rests upon a personal conviction regarding the soundness and productivity of a particular theoretical framework within a particular science.

In view of this, it is easy to see that the terms phenomenal change, phenomenal movement, and phenomenal duration, for that matter, any phenomenal experience is not intrinsically less meaningful than the best accepted notions of the older sciences. Hence, one of the primary aims of the next chapter is to define these terms on the factual level.

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and others who share the tendencies of thought which have been mentioned, no concept has any denotation at all unless eventually in terms of sensuous data or imagery." Feigl, op. cit., p. 140.

DEFINITION OF PHENOMENAL DURATION

Two primary objectives will guide the course of this chapter. The first is to provide a clarification that will satisfy the formulation of meaning provided in the last chapter. The second is to provide a definitional product in accordance with current usages of the terms. In the recent past, psychologists have paid a good deal of attention to the first objective, and justly so. The second, however, has virtually been ignored and this has often led to rather silly consequences.[4] When possible, we will place each particular experimental definition within a wider context of meaning than the experiment itself provides. We will proceed by discussion of the general referents of duration.

Duration: The terms "duration", "change", and "movement" present an obvious problem of definition, since they are all at one and the same time parts of the language of philosophy, physics, psychology, and everyday vernacular. One source

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4. One only needs a peripheral acquaintance with psychology to be aware of the ingenious verbal magic practiced on many difficult problems. The 'clarification of meaning' has provided a ready formula permitting i) the problem of hunger to become 'clarified', i.e. redefined directly, as food deprivation, eating responses, statements of stomach contractions or blood chemistry; ii) the problem of thirst to become 'clarified', i.e. redefined directly, as water deprivation, drinking response or tissue dehydration; iii) the problem of anxiety to be defined as finger tremor, a galvanic response, a particular experimental task or situation, and iiii) the problem of fatigue to become one of work decrement, a change in CFF, a physiological impairment or change, etc.

book, Baldwin's Dictionary of Philosophy and Psychology,[5] devotes about two thousand words to the term change, three thousand to movement, and nine thousand to the terms "duration" and "time". These words are what Skinner might refer to as "historical products, obese in meaning." The terms of physical science, such as wave-length, atom, electromagnetic field, appear in contrast to be largely free of such widespread referents.

Accordingly, "duration" may be considered, depending upon the point of reference, in one of several broad ways. "Duration" can be considered as: i) a "time-dependent" term, e.g. as an aspect of the form of continuity and externality of parts in all real process, such as a unit of "Newtonian time" or "psychological time" or "biological time" or as: ii) a term referring to some institutionalized cultural convention allowing synchrony of social behavior, e.g. Easter-time or Eastern-Standard Time, or as; a term expressing something psychological in the sense of: iii) experience, or of: iiii) the observed overt behavior of an organism. Let us consider each in turn. In doing so two things can be accomplished, first, a latter operational definition can be correctly placed within a larger perspective, and secondly, and more importantly, in so doing the term will be separated from a manifold of extraneous implications.

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5. James M. Baldwin (ed) Dictionary of Philosophy and Psychology (New York: The MacMillan Co., 1925), Vol. I, pp. 171-173, 300-301; Vol. II, pp. 113-116, 697-704.

<u>Duration as a Time Dependent Term</u>: Duration is quite often considered to be an aspect or unit of "time". Such a reduction seems only to remove the problem of duration from a concrete to an abstract realm, and immediately involves us in a second problem, the problem of "what is time?" For this reason, if one is to utilize a "time" explanation of duration, it seems necessary to agree on two things. One must agree that the question "what is time" can be answered in some satisfactory way. Secondly, one must also agree to include only systems of time explanation in which "time" is defined independently of duration. This is to say, any answer to the question "what is time" must assert "time" independently of "duration" if it is to have any relevance whatever to the aims of this discussion. Thus, a system in which time is stated to be constituted of a complex of relations of duration and succession in the experienced order of events must be excluded, for such a system would beg the question of "duration".

Having made these qualifications we can proceed. A number of disciplines might be expected to provide absolute time systems, and, as a matter of fact, do provide such systems. For the remainder of this section we will seek to refer duration to absolute time systems within philosophy, physics, biology, and psychology.

<u>Philosophy and "Time"</u>: A satisfactory discussion of "time" in a traditional philosophical sense, with the aim of placing the term duration in its widest context, is beyond

my competence. However, it seems fair at the same time to point out that it is probably beyond anyone's present ability. So many fundamental cleavages seem to exist within ontological philosophies regarding this term that apparently even a moderately satisfactory metaphysical account of duration in terms of "time" is not at present possible. Within metaphysical systems time can refer to anything from a noumenal to an experienced object; and philosophical theories to account for this vary from those that are nativistic to those that are empirical.

Physical Time: The physical sciences provide surprisingly little help toward the clarification of the term duration via an answer to the question of "what is time." With the abandonment of Newtonian 'Absolute Time,' for example, all biological phenomena have been considerably divorced from the narrowed physical conceptualizations of "time". Time as now considered within physics is multiple. "Time" refers to the occurrence and measurement of cyclic phenomena within particular systems. It is not held to be strictly meaningful to refer to "time" apart from a specific system.

Thus the biological and psychological significance of any physical "time" measure must rest upon the validity of the assumptions relating two separate systems. The widespread speculations today regarding the effects of high velocity interplanetary travel upon life processes which have resulted in sharply conflicting conclusions regarding the human effects highlights the difficulties of doing this successfully. Actually, however, the problem of interdependence of the two systems has always been with us in the form of actuarial tables which have an obvious inadequacy with respect to biological processes. For example, one can predict natural death for individuals with only a very sizeable error.

Biological Time: Failure to find a satisfactory form for the expression of biological phenomenon within the non-biological sciences has led to the formulation of purely biological time systems. The best known example is the attempt of Du Noüy, who on the basis of extensive study of the growth of cells in tissue cultures, posited the existence of an "internal physiological time". This "internal time" of organisms does not flow at a constant rate within sidereal time. Rather, the "internal clock" governs the rates at which all vital processes unfold by dint of the fact that it is a manifestation of the specific evolutive cycle of the individual organism in question. Experienced duration Dr. Noüy held forth as an outcome, i.e., a division, of the whole regulated physiological aging process.

His treatise, Biological Time,[6] contains some experimental data showing excellent relationships between both time estimation and physiological age, and time and metabolic processes. Nonetheless, his tenets are by no means convincing,

6. P.L. Noüy, Biological Time (New York: The MacMillan Company, 1937), p. 159

because much of the subsequent experimentation does not support his theoretical notions. Notably, Schaefer and Gilliland [7] failed to find any significant relationship between heart work, blood pressure, lung work, and breathing rate and estimation of short time intervals. This was true despite the fact that the physiological indexes were made to vary greatly during the experiment. Hence, on the basis both of the small amount and the inconclusive nature of the evidence available, it would be gratuitous to identify duration with a biological time dimension.

Psychological Time: Almost all the theoretical psychological explanations of "time" that are in accord with fact deny the presence of a non-empirical time sense.[8] The one

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7. V.G. Schaefer and A.R. Gilliland, "The Relation of Time Estimation to Certain Physiological Changes," J. Exp. Psychol., XXIII (1938), pp. 545-552.

8. Woodrow in his chapter in the Handbook of Experimental Psychology says the following regarding theories of time perception:

"Time is not a thing that, like an apple, may be perceived. Stimuli and patterns of stimuli occupy physical time; and we react to such stimuli by perceptions, judgments, comparisons, estimates, etc. Whether some mental variable such as duration or protensity is an immediate property of our perception of temporal stimuli, or of mental processes in general, is a matter of some disagreement. If there is no such immediately given property, it follows that time is a concept, somewhat like the value of pieces of money, that attaches to perceptions only through a judgmental process. The ease of apparent immediacy of the temporal judgment in certain cases might be explained as the result of practice, much of it occurring in the first few years of life, in the interpretation in terms of physical time of the numerous alleged temporal cues."(S.S. Stevens (ed.), Handbook of Experimental Psychology (New York: John Wiley and Sons, Inc, 1951), p. 1235).

In a 1933 review article of psychological studies of "time" estimation, A.O. Weber stated:

"The psychological problem involved cannot be explained on the basis of objective time; rather the answer must be

possible exception to this rule is provided in the recent work of Cooper and Erickson titled "Time Distortion in Hypnosis". These writers, perhaps somewhat carelessly, speak of an awareness of the flow or passage of time made possible by a time sense.[9] In any event, the time sense concept does not seem to play a central role in the interpretation of their data nor does it seem to play a crucial part in their carefully framed definition of "seeming duration".

Duration and Social Time: All social life requires elaborate cooperation, therefore, it is almost mandatory that societies employ some external devise to synchronize activity. In effect, some scheme defining simultaneity and duration is obligatory. Sturt in her volume, The Psychology of Time[10] traces the evolution of social time from primitive societies

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sought for in the conditions that operate directly upon our conceptions of time. 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."(Psych.Bull. XXX(1930),pp.233-252). M. Sturt stated in 1925 the following:

"I have sketched in earlier chapters various stages in the development of the time-concept, and have indicated some of its more important constituents. In this chapter the aim is to show that time is a concept, and that this concept is constructed by each individual under the influence of the society in which he lives."(The Psychology of Time,London: Hartcourt Brace and Co., 1925, p. 141).

Finally, it is worthy of note that Mach held the position as early as 1897 that "time" psychologically is of empirical derivation. He says: "The entire passage of time, in fact, is dependent solely on conditions of sensuous activity." (E. Mach, Contributions to the Analysis of the Sensations, trans C.M. Williams (Chicago: Open Court Publishing Co.,1897) p. 110).

9. L.F. Cooper and M.H. Erickson, Time Distortion in Hypnosis (Baltimore: the Williams and Wilkins Co., 1954), p. 8.

10. M. Sturt, The Psychology of Time (London: Hartcourt Brace and Co., 1925), pp. 12-42.

to the modern form. She points out two historical trends discernible in the evolution of social synchronizing devices. In one case there has been a movement away from utilization of purely personal expressions of duration, to the utilization of externally observable signs of change, and finally to employment of highly abstract systems. In the other case, there has been a transition from discrete to continuous time forms. Hence, in the Western world, 'long' durations are commonly referred to some calendar, such as the scholastic, the financial, the ecclesiastical, or the common twelve month calendar. 'Short' durations, in constrast, are referred to a single standardized device, the ordinary clock.[11]

Ordinarily, of course, a "social referent" is clearly intended when the word duration is used, for language itself is a social implement. Language itself clearly intends to coordinate social behavior. Thus, we usually say (to one another) "two hours have passed for me", rather than "this job was (seemed) twice as long as that for me," and we say (to one another) "That period was five years for me," rather than "That period was (seemed) longer than another period for me," etc. In the social sense "duration" is a certain block of minutes, years, seconds, ages, etc. This social application of the term yields a great intersubjective agreement among people in social situations because conclusions reached

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11. Interestingly enough, however, the evolution has not been completed, since the clock ordinarily measures the "twenty-four hour day" in a confusing manner, by marking off two twelve hour periods, the A.M. and P.M. "times". An exception to this is the recently devised military or civil clock (civil time) which goes from 0 hour to the 2400 hour each day.

about the positions of the hands on a clock, the date on the calendar, the transitions of the earth relative to a sun, etc., can be very nearly perfect for all people. However, one conceivably could, and, in fact, occasionally does, use the phenomenal forms, but in so doing the term duration is standing for a fact that is not available to others; in so doing we are not quite playing the social game, i.e. communicating optimally to others.

The foregoing points up an important fact with respect to "for-me" durations. This fact is that even on a sheerly operational basis "for-me" duration has two very different referents. The first class of referents are the "social referents", i.e. clock duration or calendar durations and the second class are the primitive referents, e.g., phenomenal duration. Hence, it is an oversimplification to define duration as "that which the clock measures."

One cannot over-insist that social duration is only present as a concrete event in the presence of some timepiece and becomes only an abstract social concept without it. Neither can it be over-asserted that neither of these have much at all to do with what has been named "phenomenal duration". Külpe made the importance of the distinction entirely clear many years ago when he wrote the following:

> "The experiments published hitherto have unfortunately paid but little regard to the different possibilities of judgment; there has been a regrettably strong tendency to consider objective time relations as the natural objects of subjective apprehension. One of the consequences of this attitude

may be mentioned, for the sake of illustration. Until quite recently, it has passed altogether unnoticed that the basis of comparison in a quick succession of three sound stimuli is not the duration of the small intervals which they mark off, but the rapidity of succession of 1 and 2 and of 2 and 3. We now know that the observations made with these small times cannot be compared with those of longer times, in which the duration of the interval as such affords the material of estimation. This and similar confusions render the task of exposition exceedingly difficult. In certain cases it is quite impossible to discover what the object of judgment actually was."[12]

Duration as Overt Behavior: It is conceivable that duration might be studied by means of discrimination techniques in both non-human and human organisms. We have known since the reports of the "delayed reaction" and "delayed alternation" experiments by Hunter,[13] and the "trace conditioning" and "delayed conditioning" by Pavlov,[14] that non-human organisms are able to deal discriminatively with conditions that are nonsimultaneous in the clock sense.[15]

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12. O. Külpe, Outlines of Psychology (London: Swan Sonnenschein and Co., 1895), p. 382.

13. W.S. Hunter, "The Delayed Reaction in Animals and Children," Behav. Monogr., II (1913).

14. I.P. Pavlov, Conditioned Reflexes: An Investigation Into the Physiological Activity of the Cortex (London: Oxford University Press, 1927), pp. 40-41; 88-105.

15. Pavlov, however, referred to what we would call an "overt behavior duration" as a "Temporal" discrimination. For example, let us take a successful trace experiment in which an unconditioned stimulus is produced at some set rate, such as food every ½ hour, and the organism begins to respond on about the same occasion as when food was previously presented. In such a case Pavlov would credit "time" per se with being the "conditioned stimulus". (Ibid.)

B.F. Skinner,[16] in fact, explicitly discusses two types of conditioning that might provide operational definitions of "overt behavior duration". One class "Type S" (respondent) occurs when an impingement is singled out for correlation with a reinforcement under arbitrary control of the experimenter.[17] The other "Type R" (operant) is a conditioning occuring when the organism is allowed to respond freely to a continuous stimulus continuum but where receipt of reinforcement is contingent upon the response occuring at a particular point on the continuum (i.e., 30-40 seconds after presentation of light). According to Skinner the "overt behavior durations" ("temporal discriminations" in his terms) are the results of complex constellations of overlapping successive stimulation functionally organized by reinforcement.

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16. B.F. Skinner, The Behavior of Organisms (New York: D. Appleton-Century-Croft Co., Inc., 1938), pp. 266-307.

17. B.F. Skinner has questioned whether such experiments do in fact constitute instances of "temporal discrimination". He has concluded that a "unit of time" cannot acquire the properties of a conditioned stimulus. In one place he says, "As I have previously noted, the appearance of a single property in the position of a stimulus is a certain sign that the reflex is pseudo--that is, that the stimulus is discriminative rather than eliciting." (Ibid., p. 269) In another he remarks"...the laws of latency, threshold, after-discharge, and so on, are intended to apply to reflexes generally but if we permit ourselves to write S: interval of time. R as a reflex without qualification, they are meaningless when applied to such an entity. We have not only overlooked much of the process of establishing such a relation, but we emerge with an entity which has usual properties and appears to behave anomalously." (Ibid., p. 270). Skinner clearly puts the question of "temporal discrimination" apart from time although he might better have chosen a more suitable way of labeling the discrimination.

Several examples of what he considers to be temporal discriminations of "Type R" arising during periodic responding in rats are discussed. He says however that,"I have no specially designed experiments to report on the subject". His statement is probably a good resume of the status of knowledge within this problem area. Many studies have been reported which might conceivably be interpreted as bearing upon "overt behavior duration". Such interpretations are far removed from the intentions of the original workers however. A reinterpretation without further research would certainly lead to unacceptable generalizations.

Duration as Experience: When duration is spoken of as experience it may have reference to experience in an "introspective" sense or in a "phenomenal" sense. In the introspective" sense duration most often refers to one dimension of sensation, or mental content, and in essense is an event localized within the self. In contrast, "phenomenal duration" refers to an externally localized event, something that occurs out in the world and apart from the observor himself. The earliest psychologists, the psychologists of content, used the word in both senses [18] but the use of duration as an attribute is unique to them and we shall consider it now.

Attributive Duration: Külpe, Titchener, and Mach, as examples, all considered quality, duration, intensity, and extension as being the basic attributes of sensation. Külpe

18. Külpe, op. cit.

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more than anyone else lucidly formulated a position with respect to attributive duration. In his treatise, Outlines of Psychology, Külpe distinguishes between attributive duration and the other three sensory attributes as well as attributive duration and "interval". This work will be referred to in the ensuing paragraphs.

Duration was named as one of the attributes given in sensation and feeling, and, as such, was a universal attribute coordinate with quality and intensity. Duration as an attribute was defined only by its magnitude and never by its referent. According to Külpe, duration appears as "the simplest temporal predicate - - - the attribute of a single conscious process."[19] Attributive duration, unlike quality, intensity, and extensity was the only sensory attribute measurable by objective procedures.[20]

The interval, on the other hand, was one of the predicates of duration, the "endurance of something," i.e., interval was what we have called phenomenal duration.[21] "Interval duration" was said to involve "temporal position", i.e., an earlier or later place in the succession of conscious processes, plus event frequencies, and event recurrences. We may quote Külpe to gain an understanding regarding the

19. Ibid.

20. Ibid., p. 280

21. Ibid.

relationship the new psychology assumed to exist between those related variables.

> "We do not mean, of course, that the judgment of duration must, therefore, necessarily be the most original in the psychology of time, i.e., that it is chronologically prior to all the others and is the foundation of any one of them in the particular case. We believe, on the contrary, that all the different kinds of temporal judgment which we have mentioned, - duration or interval, direction and rapidity of succession, number and period,- are capable of an equally direct or immediate application." [22]

These distinctions no longer have especial importance because the systematic introspective programs of the psychologies of sensation have all, to the present writer's knowledge, been abandoned. [23] Hence, we will now turn to consider phenomenal duration.

Phenomenal Duration: Early in the history of psychology Mach made an observation to the effect that durations are organizations of multiple and vastly different events, and that these organizations are not expressible solely by reference to the recognizable constituents. The flavor of the phenomenal given is evident in the following passage translated from Beitrage zur Analyse der Empfindungen:

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22. Ibid.

23. Külpe changed his views considerably after 1900 and represented a psychology more phenomenalogical and less elementistic. E.B. Titchener later modified similar views. In final form duration as well as extension and intensity were "given" as qualities. Systematic Psychology: Prolegomena (New York: MacMillan Co., 1929) Wundt never considered duration per se. Rather, he referred to "time" as a "mode of complex perceptual organization." Sensation and Perception in the History of Experimental Psychology (New York: Appleton, Century, Crofts, Inc., 1942), p. 574.

> "That a definite, specific time-sensation exists, appears to me beyond all doubt. The rhythmical identity of the two adjoined measures, which vary utterly in the order of their tones, is immediately recognized. We have not to do here with a matter of the understanding or of reflexion, but with one of sensation. In the same manner that bodies of different colors may possess the same spatial form, so here we have two tonal entities which, acoustically, are differently colored, but possess the same temporal form. As in the one case we pick out by an immediate act of feeling the identical spatial components, so here we immediately detect the identical temporal components, or the sameness of the rhythm."[24]

James made a pictorial but similar description. In one place he likens durations to a ship:

> "With a bow and a stern, as it were, - a rearward - and a forward-looking end." [25]

and in another he says that:

> "We do not first feel one end and then feel the other after it, and from the perception of the succession infer an interval of time between, but we seem to feel the interval of time as a whole, with its two ends embedded in it."[26]

and in still another place he says;

> "A succession of feelings, in and of itself, is not a feeling of succession. And since, to our successive feelings, a feeling of succession is added, that must be treated as an additional fact requiring its own elucidation." [27]

Hence both James and Mach in a way anticipated later molar outlooks although in large part their psychologies made reference to elementary properties and the lays of their synthesis.

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24. E. Mach, Contributions to the Analysis of the Sensations, trans. C.M. Williams (Chicago: Open Court Publishing Co., 1897), p. 110.
25. William James, Principles of Psychology(New York: Dover Publications Inc., 1950), p. 609.
26. Ibid., p. 610
27. Ibid., p. 628

The formal recognition of the duration as a phenomenally whole experience of course awaited the formulation of the theoretical principles laid down by the Wertheimer, Koffka, Köhler school of Gestalt Psychology. Our formulation of duration as the experience of the "for-me endurance of an internal event" is phenomenal in nature and agrees with the Gestalt formulation of sensory experience. Their fundamental re-orientation to problems of experience are too well known to require further elaboration here. The Gestalt position did not, of course, alter the facts of observation but served solely to place them within an adequate theoretical framework.

Surprisingly enough, almost, if not all, the solid experimental work related to phenomenal duration in the early period of psychology, came from the psychology of the introspectionists. Külpe's "duration of something", i.e., the "interval", is identical to the phenomenal duration if the former fact is stripped of systematic connotations. The early psychologists of sensation asked two questions regarding the "duration of something" and their answers are of concern to us because they provide the beginnings of an empirical frame of reference for the term. One of the questions had to do with the "least duration" discriminable and the other had to do with the possibility of establishing a functional clarification of phenomenal duration.

The answer given to the question, "what is the least duration discriminable?" seems to depend upon both the modality and the method used. Külpe points these difficulties out in considerable detail.[28] Generally these studies agree to the fact that the least interval is smallest in the auditory modality and largest in the cutaneous modality. Most of the source books give an interval of 1/500 of a second for the ear, 1/20 of a second for the eye, and 1/20 to 1/30 of a second for impingements yielding a report of "moderate pressure". Technical reasons prevented study of other modalities. There is also some doubt that much of the least interval discrimination studies have much at all to do with durations in a strict sense, because the methods at that time employed the "empty interval" technique. Customarily, the intervals judged were physically empty periods bounded by well-defined signals, for example, in the case of auditory intervals, by clicks. Külpe pointed out the likelihood of these discriminations being not of duration but of "frequency" or "succession" of signals.[29]

The empirical classification of experienced duration offers more for us. Introspective psychologists were universally agreed by 1900 that the "durations of something" are of three distinct types, the "small interval" type (up to .5 seconds interval), the "moderate interval" (.5 to 3.0 seconds), and the "long interval" type (plus 3.0 seconds). Külpe explains the distinction as follows:

> "The temporal judgment has three essentially distinct forms; one with 'small' intervals up to about 0.5 sec., another with 'moderate' intervals between the limits 0.5 and about 3.0 sec., and yet

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28. Külpe, _op. cit._, p. 379-397.
29. _Ibid._, p. 281

> another with 'larger' intervals beyond 3.0 sec. In estimating the very smallest times we do not compare the magnitude of pairs of two intervals, but the rapidity of succession of two impressions. In estimating moderate intervals we really compare the time-lengths themselves. Neither method is ordinarily applicable to large intervals, and we consequently make our estimation of them by indirect means, - by the help of a subjective revival of the limiting impression, or of the contents of the time as it passes (phases of respiration or what not), etc. It is plain that these three different cases are not by any means coordinate."[30]

This parting shot from Külpe concludes our general discussion of duration. Subsequent work will be reported in the section titled Prior Experimentation.

<u>Operational Denotation of Phenomenal Duration</u>: We have just given a general characterization of phenomenal duration. It is now necessary to describe possible experimental equivalents of this term.

A recent article discusses four operational possibilities commonly used in investigations of "duration". The first of these, "the method of verbal estimation," requires the subject to estimate verbally the clock time elapsed during the phenomenal duration. The second, the "method of production" demands that the subject judge a phenomenal duration equal to that of a standard clock duration. Under this condition, the subject is typically instructed to signal the experimenter when a given number of seconds or minutes have elapsed. The third method, named the "method of reproduction," requires the reproduction of a standard interval, the standard being given as a concrete experience. In this case, the

30. <u>Ibid</u>, p. 386.

experimenter asks the subject to attend to the duration of an event and then to reproduce an equivalent phenomenal duration. The remaining method, "the method of comparison", is similar to the third in that the standard interval is given as a concrete experience. It is different, however, in that the experimenter presents another concrete duration and asks the subject to compare the two and report whether the second is longer, shorter, or equal to the first.

The following can be said regarding these four methods; the first two methods are unacceptable empirically, because they must assume some sort of "time sense" existing apart from observation of a physical clock. That is a time impression is assumed to be the empirical referent for the directions. The questionable notion of an a-priori phenomenal time-sense owes its origin to Kant, and has been criticized by empiricists since the time of Wundt at least. While Bartley [31] discusses numerous aspects of human behavior, such as sleep and waking states, periods of ovulation in the female, temperament change, etc., that can be fairly expressed as cyclic manifestations, there is little or no empirical evidence supporting the notion of an "internal clock" in the sense of a mechanical internal regulating device. In addidition, one would seem to have absolutely no empirical reason to suspect that such a mechanism, if it did exist, would be coordinated with the Naval observatory time signals.

31. S.H. Bartley, Fatigue and Impairment in Man, (New York: McGray-Hill Book Company, Inc., 1947),pp.240-301.

The third method, that of reproduction, is less desirable than the method of comparison because the observor's point of reference is altered when the experimenter goes from the standard to the variable condition. In other words, the "method of reproduction" requires the subject to passively wait for a standard interval to pass and then to actively reproduce an identical phenomenal duration. On the other hand, the "method of comparison" provides the most satisfactory control of attitude by keeping the method of observation constant, i.e., the observor passively observes both durations.

Hence, the Method of Comparison is to be considered as the operational equivalent of the term phenomenal duration.

SUMMARY

On the basis of the foregoing discussion, we must express regret that the term "duration" always implies "time". Enlarging upon the term in this manner brings about needless difficulty. The equating of duration with "time" is apt to elicit diverse and conflicting theoretical expectations for empirical studies of duration. Too often these expectations are apt to be quite "un-matter of fact" or remote from the problem at hand.

Durations that do not necessarily imply time are: i) duration as a discrimination of experimentally set intervals, ii) duration as an universal attribute of mental elements, and, iii) phenomenal duration. However, the relation of discriminative duration to attributive duration and phenomenal duration is not known at present, and the relation of attributive duration to phenomenal duration is largely a matter of academic interest. Therefore, phenomenal duration should not be viewed as an aspect of an independent time, nor does it bear any known empirical relation to "clock time" or time discriminations measured by overt behavior.

At this point, phenomenal duration can be viewed positively as a term standing for a rather isolated matter of fact: This fact is the experience of a "for-me endurance of an external event". The experience itself is phenomenal and hence is a molar experience existing in its own right and transcending the elements recognizeable within it. This

endurance cannot be given a clearly defined lower limit on the clock scale, although the endurance can be given a three fold classification on a functional basis. Operationally, "phenomenal duration consists of reports of "for-me" endurances of external events via the method of comparison.

DEFINITION OF PHENOMENAL CHANGE

The preceding distinctions and these to follow are not mere pedantry on the writer's part. It is solely on the basis of such careful phenomenal definitions that we are both able to usefully employ the phenomenal terms, and to clearly distinguish one phenomenal variable from another. To do otherwise is to risk, if not invite, an irrelevant or nonsensical result.

Change: Baldwin's Dictionary discusses the term change at some length. According to the source, the term in the widest sense denotes the presence of any variation or difference, whether or not any identity is involved. This definition includes what we commonly call movement, modification, growth, development, etc., as well as more specific kinds of change. A somewhat less general usage than the above distinguishes two kinds of change conditions. First, a condition can be called a change if a distinguishable thing exists which either did not exist at the immediately preceding moment, or does not exist at the immediately succeding moment. Secondly, a condition can be called a change when an enduring thing is said to have undergone an alternation.[32] Since we are concerned with experimental conditions which involve an identity, i.e., we are concerned with the relationships of "phenomenal change" and "phenomenal movement" with respect to the "forme endurance of an external event," an instance of the second

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32. Baldwin, op. cit., Vol. 1, p. 171-173.

usage above will be selected as our definition of "change".

Thus, "change" is defined as a condition in which some identifiable thing is evolving. In such a condition most of the parts, but not all, are the same on any two occasions of observation.

Phenomenal Change: A good example of phenomenal change is provided by a kaleidoscope in operation. Other systems analogous in principle but less complex in design and phenomenal effect can also be used. Such a symplified kaleidoscope will be described in the experimental sections. The most important is not the particular method employed, however, but the phenomenal end result is an on-going transformation occuring within a phenomenal whole. Thus a kaleidoscopic instrument alone will not suffice a priori as a satisfactory operational definition of "phenomenal change". It must for example be directly ascertained under the conditions of operation that the physical effect produced is not experienced as a system of moving things, each existing in its own right. The procedure must result in the experience of an identifiable unitary thing undergoing continual modification. The term phenomenal change, therefore, will be given the following meaning.

"Phenomenal Change" is defined as a condition in which change is observed and so reported by an observor to the experimenter in an experimental setting.

DEFINITION OF PHENOMENAL MOVEMENT

As the previous discussion pointed out, "movement" in a generic sense is a species of change. In a specific sense, however, the word "movement" ordinarily serves to denote a specific kind of change. Bearing the generic notion in mind, the following definition can be usefully made.

Movement: Movement refers to a system of things in which the things have a salient continuity and direction relative to one another. Such a system is totally different upon any two occasions of observation.

Phenomenal Movement: A good example of phenomenal movement is provided when a stationary light is projected through a rotating glass disc covered with cellophane confetti onto a surface. If the pieces of confetti are of small enough size, colors will start on one side of the surface, move to the other, and disappear in a never ending succession. Such a device will be described later in some detail. A warning similar to that given in the case of phenomenal change apparatus must be made here respecting the phenomenal movement apparatus. It must be pointed out that any piece of equipment will suffice, providing the physical effect produced by this equipment is experienced by the subject as a system of moving things, each existing in its own right. The denotation is applicable only to apparatus which in operation produces a report from the observer to the effect that he experiences the surface as being separate from the things moving.

The term "phenomenal movement" therefore will be given the following meaning.

Phenomenal movement is defined as a condition in which movement is observed and so reported by an observer to the experimenter in an experimental setting.

Thus, the outstanding difference between phenomenal change and phenomenal movement is provided by the identification of phenomenal change with the constant evolution of a unitary thing and phenomenal movement with the transition of multiple things across a surface.

CHAPTER II

PRIOR EXPERIMENTATION UPON THE PHENOMENAL VARIABLES

II. PRIOR EXPERIMENTATION

Over the years the study of "time" has taken various forms and has presented problems for workers in diverse fields. A good part of the research might fairly be said to provide results that bear upon problems related to phenomenal duration. Investigations have considered the effect of filled versus unfilled intervals, individual differences in judgment, the contribution of body rhythm, organic and kinesthetic factors, the contribution of learned factors, and genetic variables. Still there has been a remarkable oversight. Despite the fact that all time systems and all durations always have to do with some kind of change, there is almost a complete lack of direct research into this relationship. For this reason the review of the literature will not be extensive and some of the material reviewed will not be as much to the point as one might desire.

Phenomenal duration and change: The experimental work dealing with short interval estimation and short interval reproduction has been centered around questions regarding the applicability of Weber's Law, the location of indifference zones, the effects and production of rhythm, the discovery of empirical criteria employed by subjects in "time" estimation tasks, and the relation between physical events and the phenomenal responses. Since phenomenal change refers to an abruption in a unified "for-me" experience of an external event some of the work in the last two short interval categories will be reviewed.

The review will not be comprehensive for three reasons; i) the experimental results reported are not by and large internally consistent; ii) the physical intervals reported are very short; iii) the manipulations made were often minor in nature and beside the point as far as the later research problems of this thesis are concerned. Reports of the earlier work will be reviewed from secondary sources.

Hall and Jastrow in 1886 reported results obtained by having subjects compare filled with empty intervals. The intervals were from 1 to 3 seconds. The filling consisted of a series of auditory abruptions in the form of clicks. The abruptions increased the phenomenal duration of the filled intervals when compared to the unfilled, although the presentation order of the auditory targets and the clock durations sometimes obliterated the abbreviation.[1]

Ejner and Kraeplin, in 1889, filled intervals of 30 to 240 seconds with metronome beats and compared the phenomenal duration of these to empty intervals equally as long. They found the reproductions were consistently longer than the standards independent of whether the intervals were experimentally empty or filled.[2]

Meuman in 1896 reported experiments relating temporal values and various fillings of intervals to phenomenal duration. The standard intervals varied from 0.3 to 10.0 seconds,

1. D. Triplett, "The Relation Between the Physical Pattern and the Reproduction of Short Temporal Intervals," Psychol. Mong. XLI (1931), p. 203, p. 210.
2. Ibid., p. 204

and the fillings were achieved by smooth tones and clicks. He concluded that continuous filling by smooth tones led to a shortening of phenomenal duration in cases where the filled interval preceded the empty. With the opposite order an empty interval followed by a continuously filled, an abbreviation resulted only in the middle range of temporal values. In contrast, to both of the above findings, the abruptions produced by clicks showed no order effect but produced a phenomenal shortening in the shorter range and a "lengthening in the case of the longer values."[3]

Gulliksen in 1927 attempted to ascertain the influence of various "situations" on time estimation. Two of his conditions required the subjects to estimate the clock time of auditory units. One of these units was a clock interval of 200 seconds, filled with a metronome beating 66 times and a metronome beating 184 times per minute. The experimental results showed that both intervals were overestimated by clock standards and that the overestimation was greatest in the case of the slow metronome. The average estimate was 223.7 seconds for the slow metronome and 214.1 for the rapid. The standard deviations, however, were 92.4 and 85.2, respectively.[4]

Roelofs and Zeeman[5] in 1949 published an account of an extended series of experimental investigations. The studies

3. Ibid. p. 205
4. H. Gulliksen, "The Influence of Occupation Upon the Perception of Time," J. Exp. Psychol., X(1927),pp.52-59.
5. O. Roelofs and W.P.C. Zeeman,"The Subjective Duration of Time Intervals, 1," Acta Psychol., VI (1949), pp. 127-177.

had to do with the effect of interruptions of various lengths on the phenomenal duration of visual targets with short exposure times. The method of comparison was used to express the experimental outcome. The subjects were required to compare the phenomenal duration of a continuously exposed luminous square with the phenomenal duration of a similar square with the phenomenal duration of a similar square exposed with interruptions. The standard intervals used varied from 420 msec. to 1,800 msec. They found that empty intervals of 1800 msec., i.e. an interval between two brief flashes of a visual target, were experienced as being shorter than continuously filled intervals. The average shortening they report to be about 12.3% of the continuously filled interval. Interrupted intervals of 420 to 1800 msec. also resulted in shorter phenomenal durations than those continuously filled. The effect of the abruptions was enhanced as the temporal values of both intervals were increased. Thus, an interval of 1800 msec. with a break of 900 msec. when compared to a continuously exposed target, resulted in an average shortening of 24.6% while a 420 msec. interval with a break of 210 msec. produced an average shortening of only 8%. The order of presentation affected the reports. The first tended to be reported as shorter and the second as longer. This order effect was not so large as that produced by the abruptions in the duration.

In a later article Roslofs and Zeeman[6] cite additional

6. <u>Ibid.</u>, pp. 289-336.

experimental data using longer intervals. The experimental procedure was about the same as above. They report that with intervals of 3.200 msec., breaks of 400-640 msec. did not produce differences in phenomenal duration. The order effect was also altered for longer intervals. With intervals shorter than 700—800 msec. the second in order tended to be reported as longer, and with intervals of above 1600 msec. all biasing gradually decreased.

Hirsh, Bilger, and Deatherage recently reported a study concerning the changes in phenomenal duration accompanying changes in experiential background. In a series of experiments subjects were required to reproduce the phenomenal durations of tones and lights when the context in which the tones and lights occurred was altered from ambient light or dark to ambient noise or quiet. Durations of 1,2,4, and 16 seconds were used and the results were clearcut. The ambient conditions of darkness or light had no influence upon the phenomenal duration of either tones or light, while background noise has a marked effect. Reproductions of standard intervals of phenomenal duration of tones or lights were made much longer when the standard was presented in the quiet and the reproduction rendered in noise. This indicates that ambient noise shortens phenomenal duration. The opposite was true when the auditory targets were given as standards in the noise and reproduced in quiet. In this case ambient quiet served to lengthen phenomenal duration. Moreover, manipulation of amount of ambient noise showed that the response followed the noise level expressed in db's, the curve describing a curvilinear function. The authors acknowledge that the ambient noise conditions were not the phenomenal equivalents of ambient light conditions, since they did not correspond to one another on the visual-auditory scale of equivalence constructed by Stevens.[7]

Phenomenal duration and movement: Probably the earliest observations related to the problem were made by De Silva in 1928.[8] His primary interest was the study of various factors contributing to maximal velocity in apparent movement. It was known then on the basis of Korte's 1919 research that there were certain strict relationships between beta movement and the distance separating the experimental targets, the size of the target, the time pause between target presentations, etc. De Silva's exhaustive extension of Korte's work need not concern us here except as if related clock time to phenomenal speed, and related physical velocity to phenomenal duration. Using the very short exposure times necessary for beta movement he found that the clock time element was most fundamentally related to phenomenal speed, and also that the angular physical velocity was closely related to the "duration of sensation".

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7. I.J. Hirsh, R.C. Bilger, and B.H. Deatherage, "The Effect of Auditory and Visual Background on Apparent Duration," Amer. J. Psychol., LIX (No. 4, 1956), pp. 561-575.
8. H.R. DeSilva, "Kinematographic Movement of Parallel Lines," J. Gen. Psychol., I (1928), pp. 550-557.

The studies of Helson and King concerning the Tau Effect are the next studies of note. These investigators showed the importance of the time factor upon apparent movement on the cutaneous membrane. Their results led to the conclusion that, "The temporal factor enters as an integral part of the causal complex determining the experience of Space."[9] (p. 216). The time pauses used were fractions of a second and no mention was made of phenomenal duration or the phenomenal velocities associated with the movement.[10]

Brown reported a series of experiments in 1931 related to those of De Silva. His first study dealt with target and field factors related to the production of increases in phenomenal velocity. His main findings related the effect of field properties upon phenomenal velocity and hence do not concern us here. However, he did report that introspective reports of his subjects indicated a positive relationship between phenomenal velocity and phenomenal duration.[11]

In a later experiment Brown[12] investigated the relationship between phenomenal velocity and phenomenal time (i.e. phenomenal duration) directly. The method of comparison was used with intervals of around three seconds. The experimental procedure was to allow a subject to adjust the velocity of a moving

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9. H. Helson and S.M. King, "The Tau Effect--an Example of Psychological Relativity," J. Exp. Psychol., XIV (1931), p. 216.
10. Ibid., pp. 202-218
11. J.F. Brown, "The Visual Perception of Velocity," Psychol. Forsch., XIV (1931), pp. 199-232.
12. J.F. Brown, "On Time Perception in Visual Movement Fields," Psychol. Forsch. XIV(1931), pp. 233-248.

field of black targets until the phenomenal duration of transit of a target across an aperture was judged as being equal to the phenomenal duration of an auditory signal. Aspects of the gestalt were manipulated, such as breadth of the field and illumination of the field. Brown hoped to demonstrate the equation phenomenal velocity = phenomenal space/ phenomenal time ($u = s/t$) is as valid a relation as the physical equation $V = S/T$. In order to do this he had to show that where the traveling targets were experimentally exposed and observed, the phenomenal duration would balance with the phenomenal rate of movement and the phenomenal space values in the manner demanded by the equation. On the basis of his previous work he knew how to realize experimental field conditions that would alter the phenomenal velocity by a measurable amount. He reasoned that if he would, for example, decrease the phenomenal velocity of the target a phenomenal 20% he should at the same time decrease phenomenal durations by a similar percent of the <u>physical time</u> of the standard duration. The outcome of his experiments led to the generalization that "....the phenomenal time necessary for visually perceived movements to cover phenomenally equal spaces varies inversely with the phenomenal velocity."[13]

Some years later, D. Cartwright[14] challanged Brown's

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13. Ibid., p. 247
14. D. Cartwright, "On Visual Speed," <u>Psychol</u>. <u>Forsch</u>. XXII (1938), pp. 320-342.

conclusions maintaining that Brown's results were actually incompatable with his theory. His criticism need not occupy us here because a reply by Brown several months later [15] showed that Cartwright's criticism was poorly founded.

The grounds that Brown should have been criticized upon, and was not, are the conceptual. Brown has no legitimate reason, that he formally states, for expecting the isomorphic relation he tests. The physical statement V=S/T is an analytic (logical) not an empirical truth. The physical statement is true only because of the way the physicist chooses to use his language, i.e. velocity is defined that way, as S/T. A quote from W. Westphal's [16] Kleines Lehrbuch Der Physik will make this particularly clear. He says:

> "If a physical magnitude is to be measured, it must be known precisely what is meant by it, or one can also say an unequivocal measuring prescription, must be given. One should never forget that a physical definition does not meet its purpose if it does not indicate exactly how the defined magnitude is to be measured.
>
> As it turns out the great majority of all physical magnitudes can be defined through a very small number of a-priori given basic magnitudes. It is actually arbitrary which magnitudes are chosen as basic magnitudes; they must only be independent from one another, that is to say, none of them must be definable through the rest. All other magnitudes are derived magnitudes. An example is

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15. J. Brown, "The Dynamics of Visual Speed, Time, and Space: A Reply to Cartwright, Köhler, and Wallach," Jour. Psychol, VIII(1939), pp. 237-246.
16. W. Westfall, Kleines Lehrbuch Der Physik. (Berlin: Springer-Verlag, 1953), p. 2.

> velocity, which is defined by means of the basic magnitudes distance and time, as the ratio distance:time. A system of such basic magnitudes and the magnitudes derived from them is called a system of measurement."[17]

Brown, on the other hand, treated <u>all of the phenomenal variables as empirical</u>. Thus, there can be no question of isomorphism even though Brown's v=s/t <u>did</u> function empirically. This strongly suggests that Brown may have misunderstood the implication of his results. Another possible explanation of his results will be entertained later.

Cohen,[18] and in another article, Cohen, Hansel, and Sylvester [19] report studies relating phenomenal duration and spatial factors by the use of three visual targets timed to give beta movement. The study is thus analogous to that

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17. Wenn man eine physikalische Grösse messen will, muss man zunächst genau wissen, was man unter ihr versteht. Es muss von ihr eine ganz eindeutige <u>Begriffsbetimmumng</u> (<u>Definition</u>) gegeben sein, man kann ebensogut auch sagen: eine eindeutige <u>Messvorschrift</u>. Man vergesse nie, dass eine physikalische Definition ihren Zweck verfehlt, wenn sie nicht genau angibt, wie die definierte Grösse gemessen werden soll.
Er erweist sich, dass man die ganz überwiegende Mehrzahl der physikalischen Grössen durch eine sehr Kleine Zahl von vorweg (a priori) gegebenen <u>Grundgrössen</u> definieren kann. Welche Grössen man als Grundgrössen wählt, ist an sich willkürlich; sie müssen nur voneinander unabhängig sein, d.h., Die weiteren Grössen heissen <u>abgeleitete Grössen</u>. Ein Beispiel ist die Geschwindigkeit, die mittels der Grundgrössen Länge und Zeit als das Verhältnis Weglänge: Zeit definiert ist. Ein System solcher Grundgrössen und der von ihnen abgeleiteten Grössen heisst ein <u>Massystem</u>. <u>Ibid</u>.

18. J. Cohen, "The Experience of Time," <u>Acta Psychol</u>, X(1954), pp. 207-219.

19. J. Cohen, C.E.M. Hansel, and J.D. Sylvester, "A New Phenomena in Time Judgment," <u>Nature</u>, CLXXII (1953), p. 901.

of Helson and King with respect to the Tau effect and uses very short time separations in the neighborhood of 0.5 seconds. The subjects in these experiments were required to divide the interval given visually into two equal phenomenally equal durations. The targets were seen as three horizontally located flashes of light, equal in brightness but differing in distance from one another. The distance from flash a to flash b was greater than the distance from b to c, or vice versa. By adjusting a lever the subjects were able to control the timing of the center flash and were instructed to adjust the light so that the time was the same between a and b as b and c.

Cohen, Hansel, and Sylvester [20] have subsequently reported more carefully controlled studies that confirm their earlier results. Most significantly, the later studies indicate the spatial-phenomenal duration relations hold for target conditions not producing beta movement. In addition, the later studies indicate the effect to be most pronounced in the downward direction and least pronounced in the upward direction.[21]

In 1951 Roelofs and Zeeman[22] reported several experimental studies differing from those reported above in several

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20. J. Cohen, C.E.M. Hansel, and J.D. Sylvester, "Interdependence of Space, Time, and Movement," Acta Psychol., XI(1955), pp. 361-372.

21. Several additional studies on the relation of phenomenal duration and spatial factors were reported in the Japanese Journal of Experimental Psychology by M. Abbe in 1936 and 1937. These studies seem to have produced about the same results as those reviewed, although the method used was that of comparison. For this reason and because short temporal durations were used, they were not ordered by inter-library service.

22. C.O. Roelofs and W.P.C. Zeeman, "Influences of Different

respects. The experiments aimed to ascertain the influence of both spatial displacement and velocity, i.e., relative displacement per unit of time, upon phenomenal duration. They required the subjects to compare the duration of fixed to moving targets, and moving to moving targets. The targets were squares in all cases and the presentation time of the standard varied in steps from 3,200 to 200 msec. The displacements and velocities associated with the different standard times varied from a spatial displacement of 3 cm. at a velocity of 7.5 cm./sec. to a spatial displacement of 24 cm. at a velocity of 30 cm./sec. In some instances when the spatial displacements were less than 12 cm., the velocity reached 60 cm./sec. The most clearcut funding was that moving presentations are experienced differently than stationary targets. This relationship is somewhat complex, however. They found that; i) the longest standard time, 3,200 msec., brought about no differences between moving and fixed targets; ii) exposures between 1,600 and 800 msec. with higher velocities and larger displacements produced apparent lengthening of the comparison interval; iii) when the fixed target was set at 400 msec., the higher velocities and displacements produced an apparent shortening. This effect is the opposite of that found in the middle length intervals; iiii) setting the standard at the shortest interval, 200 msec., resulted in an apparent lengthening, the lengthening increasing as the displace-

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Sequences of Optical Stimuli on the Estimation of Duration of a Given Interval of Time," Acta Psychol., VIII(1951-1952),pp.89-128.

ments and velocities increased. These findings led the investigators to conclude that velocity is the important feature with longer target intervals and that displacement is the important feature with shorter target intervals. This would mean that velocity and displacement affect the experimental outcome in opposing ways. While this conclusion is in accord with the other finding reviewed in this section, they seem to be unwarrented by the data. The longest interval, i.e., 3,200 msec., brought about no differences and the shortest interval, i.e., 200 msec., had an effect opposing the conclusion. Nonetheless, it is important to recognize the possibility that phenomenal duration may perhaps be based on differing aspects from visual situation to visual situation even when the changes are relatively minor in a physical sense.

Summary: Most of the studies indicate that when abruptions are introjected into experimentally given intervals, these affect the observer's judgments of these intervals. Importantly, one study of Hirsh, Bilger, and Deatherage demonstrates the particular sensitivity of phenomenal duration to differences in the level of ambient auditory events. This outcome agrees well with experimental facts reported by introspective psychologists. The introspective psychologists showed the least interval to have the smallest value in the auditory modality. The literature contributes disappointingly little, however, toward the formulation of general hypothesis regarding the effects of phenomenal change upon phenomenal duration. The reasons for this are the following; i) the results reported are conflicting, ii) the results are dependent upon the short intervals used, iii) the results also seem to be too dependent upon the experimental method used, iiii) exceedingly simple abruptions were ordinarily used, usually, for that matter, only single abruptions, iiiii) the physical abruptions were not given an adequate phenomenal definition.

Studies have been made of the effect of movement upon short phenomenal durations. The studies ordinarily have used intervals around a length necessary to produce beta movement, e.g. 600 msec. The studies generally indicate that if other factors are held constant, phenomenal duration will decrease as phenomenal speed and physical velocity are increased. That is, the equation $v = d/t$ is generally satisfied in empirical test situations. This general finding is of restricted importance, however, if the task is that of framing a general expectation concerning the relation of longer and more complex phenomenal movements to phenomenal duration. Roelofs and Zeemans studies relating phenomenal speeds and physical velocities to phenomenal durations suggests that the effects of these variables may be closely related to the short intervals ordinarily used in the experiments. They may be ineffectual or exert an opposing effect outside the short interval range. Obviously identical criticisms can be made of these studies as were made concerning those that related phenomenal

change to phenomenal duration. Hence they will not be repeated.

CHAPTER III

EXPERIMENTATION AND THE PHENOMENAL VARIABLES.

VII. STATEMENT OF THE PROBLEM:

The purpose of the present study is to investigate the relation between several classes of phenomenal events. These events are phenomenal duration, phenomenal change, and phenomenal movement. Specifically, the present studies aim to test the hypothesis that 1. phenomenal duration will vary as a function of phenomenal change, and that, 2. phenomenal duration will vary as a function of phenomenal movement. A more restricted set of hypotheses cannot be made because of the lack of a suitable framework of facts upon which to construct them.

In order to determine whether the duration is a function of phenomenal change and phenomenal movement, certain prior conditions must be fulfilled. First, we will have to provide an instrument that produces phenomenal movements and phenomenal changes that are in accord with the operational definitions of the variables given in the previous chapters. Secondly, we will have to construct scales for phenomenal change and phenomenal movement so as to be certain to avoid the pitfalls of "stimulus centered" approaches to psychological problems. Once phenomenal change and movement can be produced, measured and controlled, a wealth of experimental possibilities are open for empirical investigation.

Scaling Phenomenal Change

Experiment 1.

Purpose: The experiment was designed to obtain a psychophysical scale for the rate of phenomenal change.

Subjects: One subject was used.

Apparatus: The equipment is pictured in Figure 1. This equipment consists of three panes of 3/8" glass mounted vertically to the floor. The mounting in all cases is accomplished by having a 5/8" piece of hardwood dowling pass through the center of each glass and into a supporting bearing. The hardwood dowling is keyed to the glass discs so that the discs may be revolved by means of a driving mechanism applied to the shaft. The glass discs vary in size. The upper disc is 24" in diameter, the center disc 36" in diameter, and the lower disc 24" in diameter. The supporting shafts are all horizontal to the floor, and, relative to one another, fall in a line perpendicular to the floor. The first hardwood shaft rests 29" from the floor, the second hardwood shaft rests 48" from the floor, and the top hardwood shaft rests 58" from the floor. As the distances between the shafts are less than the diameter of the discs, both the top and bottom disc overlap the center glass about 20". The small glass discs are set slightly to the front of the center disc and do not interfere with one another when in motion. The top glass is not used in this experiment. The lower disc is driven via a Cenco mixer motor, a variable speed clutch whose shaft-end is fitted with a sprocket gear, two chains, and a 1400-1 Boston gear box. This arrangement is depicted in the lower drawing in Figure 2. An r.p.m. indicator is attached to the input side of the gear box via a flex cable as shown in the lower drawing of Figure 3. The range of the equipment matched the range of the speedometer. The relation between the measurement of physical input via the speedometer can be translated into a more general measurement by referring to Figure 5. The center disc is driven from the shaft of the lower disc by a simple v belt and v pull-up. This drive is shown in the upper-left drawing of Figure 3. Just to the rear of the overlapping section of the top and center discs is mounted a B and L projector. The projector is normally positioned at a distance that permits the beam to occupy the entire area of a screen 36" by 36" standing 6 feet away (see Figure 1).

On the glass discs previously described, through which the beam from the projectors are passed, are mounted numerous tiny pieces of cellophane. These small pieces of cellophane are of many colors and produce a "kaleidoscopic change" effect when the projectors are turned on and the discs rotated in the same direction. Since the surfaces of the discs are

moving in an opposing direction where they overlap the bits of cellophane merge and produce stronger colors than the single pieces and then the union suddenly dissipates as the bits cease to overlay each other. The drawings of Figure 2 represent the relation of the cellophane discs and light. A schematic diagram and phenomenal description of the effect on the screen is provided by Figure 4.

The screen onto which the kaleidoscope effect falls is the front of the large box-like structure shown in Figure 1. This box has an irregular shape. The box is 38" wide at both the top and bottom and 36" high in the front, but only 24" high in the back. Since the top of the box is horizontal to the floor, the bottom of the box is mounted on legs. The legs are tall enough to accomodate an ordinary chair and torso of an observer under the box. The hole is sufficiently close to the screen so that, when facing the screen, the kaleidoscope occupies the entire visual field.

The equipment is put into action by turning on the driving motors and projectors. The speed of the shafts are varied by the speed of the driving mechanisms, they have a way to produce various changes in the velocities of displacement on the screen.

The noise of the apparatus is variable and considerable. Hence, it is necessary to mask it so as to assure that the differences obtained were based upon visual observations. For this purpose a doorbell and Burgess electric paint sprayer were used. These are not pictured.

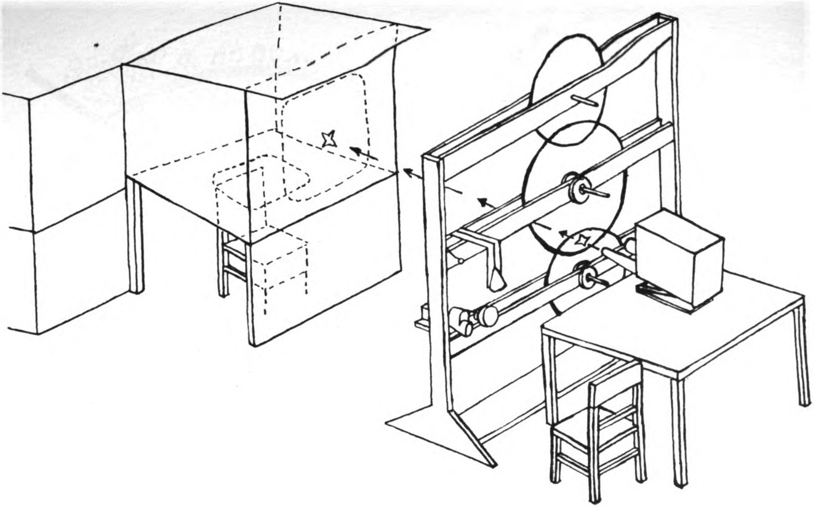

Figure 1. This shows the relationship between the various pieces of equipment described in the text.

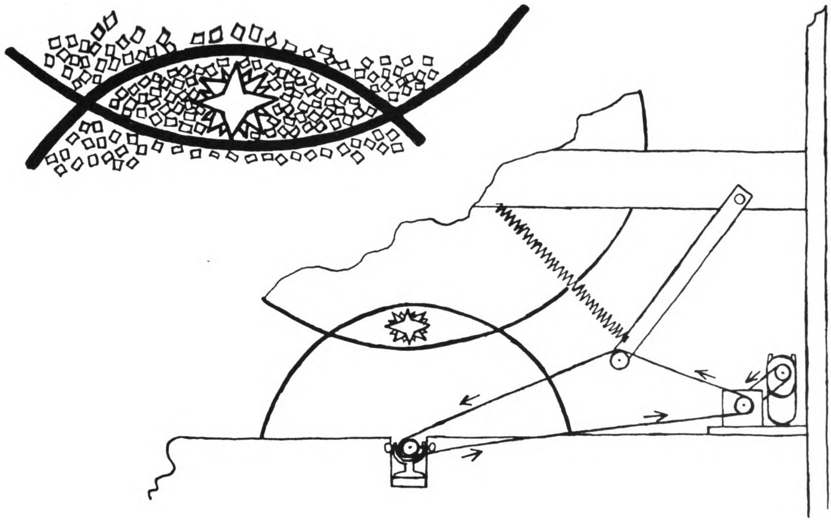

Figure 2. This represents a restricted and detailed front end view of the experimental apparatus shown in the previous figure.

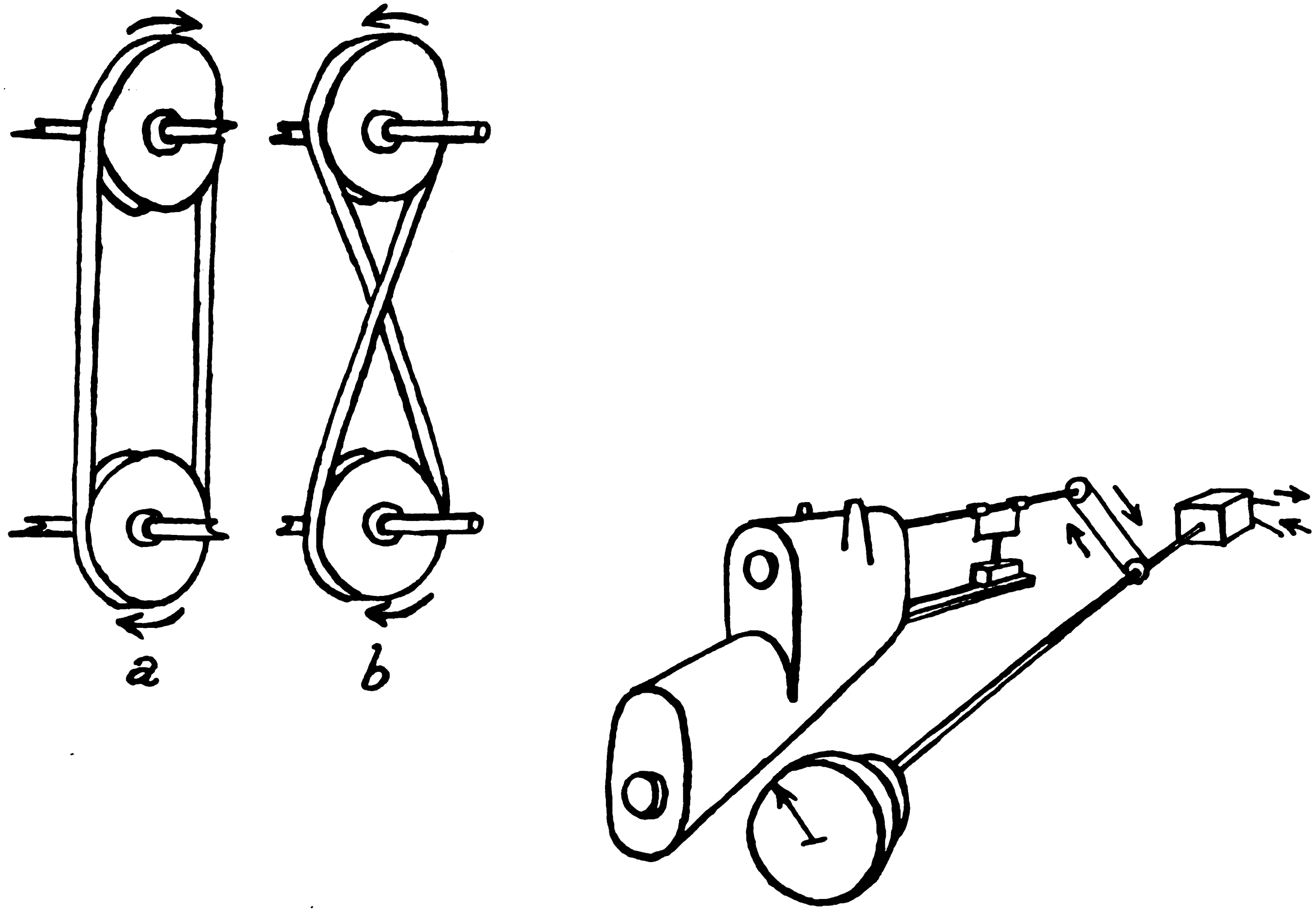

Figure 3. The upper drawing shows the belt and pulley arrangement used to change the rotation of the larger disc. An arrangement was provided to control the V-belt tension but is not pictured here. The lower drawing represents a close up of the electric motor with its variable speed clutch, the 1400-1 Boston reduction gear box, chains and sprockets, signal light, speedometer and rotation counter, and the various mountings.

Figure 4. This is a schematic representation of the change condition from the observer's point of reference. From his reference point vaguely defined areas of color appear abruptly in every quarter, remain to swirl briefly, then float gradually upward or downward or lose their identity in a newer and stronger formation. A salient feature is the unsystematic undulation of the screen itself. This produces at times a distinctive three dimensional characterization.

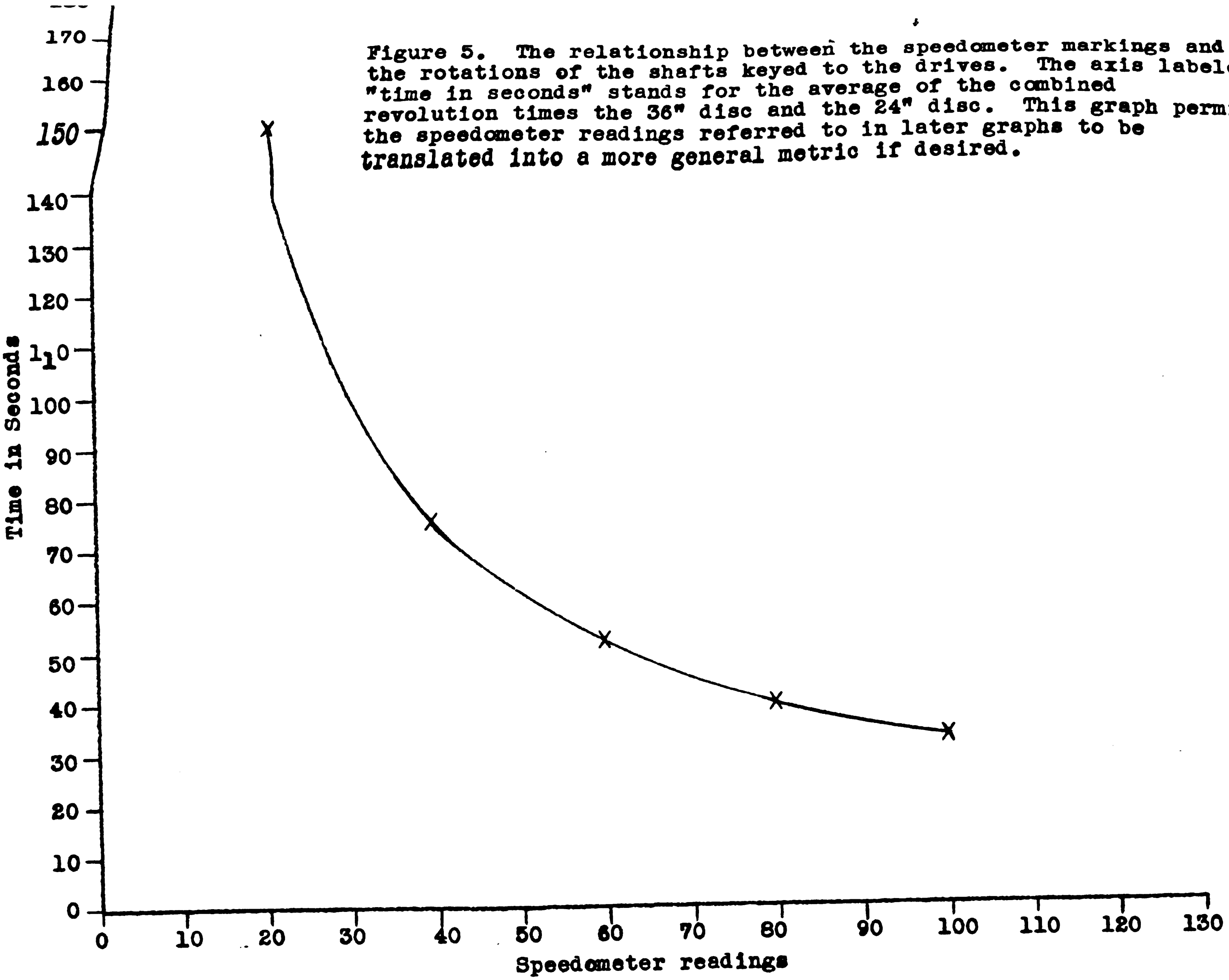

Figure 5. The relationship between the speedometer markings and the rotations of the shafts keyed to the drives. The axis labeled "time in seconds" stands for the average of the combined revolution times the 36" disc and the 24" disc. This graph permits the speedometer readings referred to in later graphs to be translated into a more general metric if desired.

Method: The method of limits or minimal changes was used.

Procedure: The observer was seated in the viewing position. He was instructed that when the kaleidoscopic change occurred he should observe it carefully and instantly report any abruption in the rate. The report was made verbally or by a pre-arranged light signal. The experimenter started the equipment and varied the rate as follows. First, the rotation speed of the discs was set at the mean value for the operative range of speeds. The shutter on the projector was then opened and the kaleidoscopic change occurred for the observer. The experimenter permitted the subject to observe the screen for a few moments and then began to make gradual adjustments of the displacement rate, up or down. The observer was not warned by the experimenter when the variable was to be manipulated nor was he told whether the manipulation would result in a more rapid or a slower rate of kaleidoscopic change.

Each interval of the scale was established by 20 ascending and 20 descending readings. The mean value served as the j.n.d. No more than 20 judgments were taken at a sitting.

Results: It was necessary to make 640 observations to exhaust the range of the equipment. The 18 step psychophysical scale resulting from the experimental procedure is pictured in Figure 6. The results seem to clearly describe a curvilinear function and an appropriate curve was fitted to the data by the free hand method. The distribution of judgments around each point is shown in Figure 7.

The data show that the j.n.d's of phenomenal change increase with increases in physical change. The graph indicates that phenomenal change does not bear a simple linear relation to physical change, however.

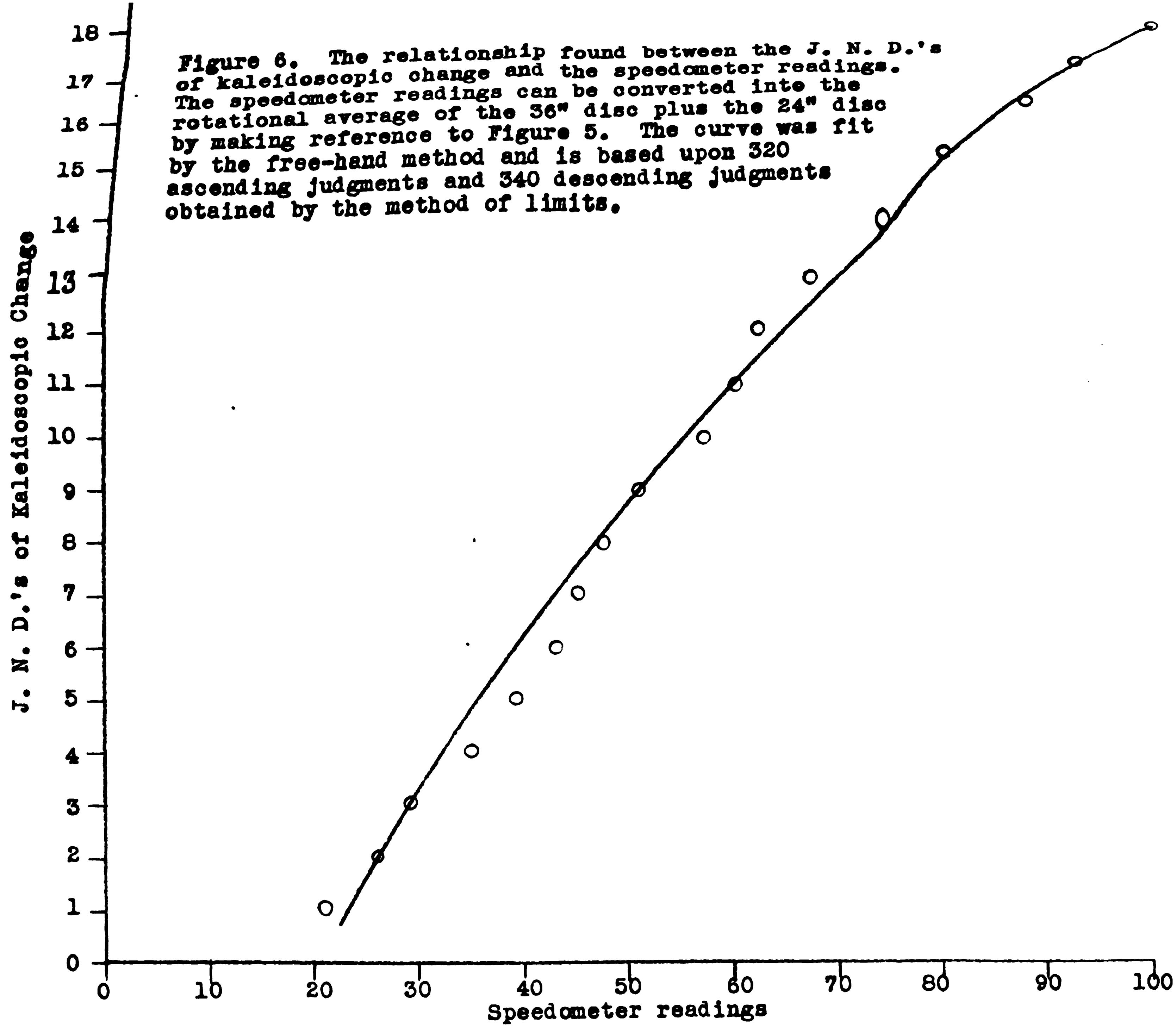

Figure 6. The relationship found between the J. N. D.'s of kaleidoscopic change and the speedometer readings. The speedometer readings can be converted into the rotational average of the 36" disc plus the 24" disc by making reference to Figure 5. The curve was fit by the free-hand method and is based upon 320 ascending judgments and 340 descending judgments obtained by the method of limits.

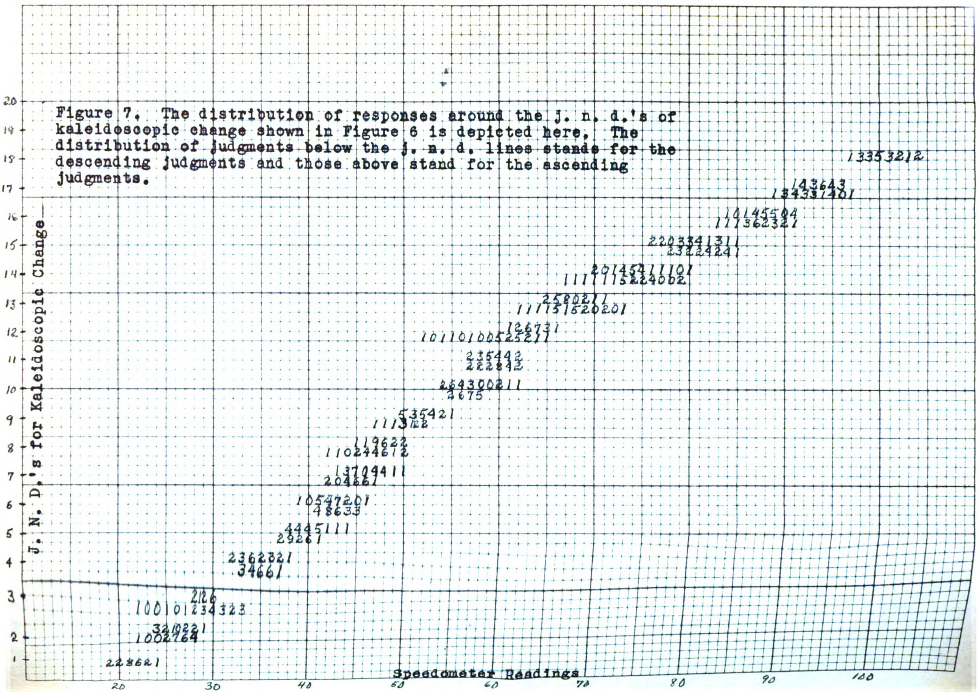

Figure 7. The distribution of responses around the j. n. d.'s of kaleidoscopic change shown in Figure 6 is depicted here. The distribution of judgments below the j. n. d. lines stands for the descending judgments and those above stand for the ascending judgments.

Conclusions: The results indicate that we have a laboratory means of producing a continuum of phenomenal changes. This continuum of change has been satisfactorily scaled by an ordinary psychophysical method. The presence of this lawful relationship means that phenomenal change can be produced, measured, and controlled. This will allow phenomenal change to be used as a quantified variable in later experiments dealing with phenomenal duration.

Scaling Phenomenal Movement

Experiment 2.

Purpose: Experiment 2 was designed to obtain a psychophysical scale for phenomenal movement.

Subjects: One subject was used.

Apparatus: The equipment was as previously described except for the following modifications. The center disc in this experiment was driven from the shaft of the lower disc by an X-ed v-belt and v-pulley set-up. This drive is shown in the upper right drawing of Figure 3. Because of the lack of availability of the desired belt length, a five inch pulley was substituted on the shaft of the center disc. The original pulley was four inches in diameter, hence the conversion curve of Figure 5 is no longer applicable. A conversion curve for phenomenal movement is presented in Figure 9. This procedure also altered the phenomenal outcome. When the belt is so arranged, the surfaces of the discs move in the same direction where they overlap. This gives a constant unidirectional flood of color from the observer's right to left. A schematic diagram and phenomenal description of the movement effect is provided by Figure 8.

Method: The method of limits or minimal changes was used.

Procedure: The observer was seated in the viewing position. He was instructed that when the system of movement was projected onto the screen he should observe it carefully and instantly report any increase or decrease in the rate of flow. The report was made verbally or by a pre-arranged light signal. The experimenter started the equipment and varied the rate as follows. First, the rotation speed of the discs was set at the mean value for the operative range of speeds. The shutter on the projector was then opened and the movement occurred for the observer. The experimenter permitted the subject to observe the screen for a few minutes and then began to make gradual adjustments of the rate of flow, either increasing or decreasing the rate. The observer was not warned by the experimenter when the variable was to be manipulated nor was he told whether the manipulation would result in a more rapid or a slower rate of movement.

Each interval of the scale was fixed by 20 ascending and 20 descending judgments. The mean value served as the j.n.d. No more than 20 judgments were taken at a sitting.

Results: It was necessary to make 560 observations to exhaust the range of the equipment. A 16 step psychophysical scale resulted from the experimentation and this scale is pictured in Figure 10. The points plotted describe a curvilinear function. An appropriate curve was fitted to the data by the free-hand method. The distribution of judgments

around each point is shown in Figure 11.

The data shows that the j.n.d's of phenomenal movement increase with increases in physical movements. The graph indicates, however, that that phenomenal movement does not bear a simple linear relationship to physical movement.

Conclusion: The experimental results indicate that we have a laboratory means of producing a continuum of phenomenal movement. This movement continuum has been adequately scaled by an ordinary psychophysical method. The presence of this lawful relationship means that phenomenal movement can be produced, measured, and controlled. This will allow phenomenal movement to be used as a quantified variable in later experiments dealing with phenomenal duration.

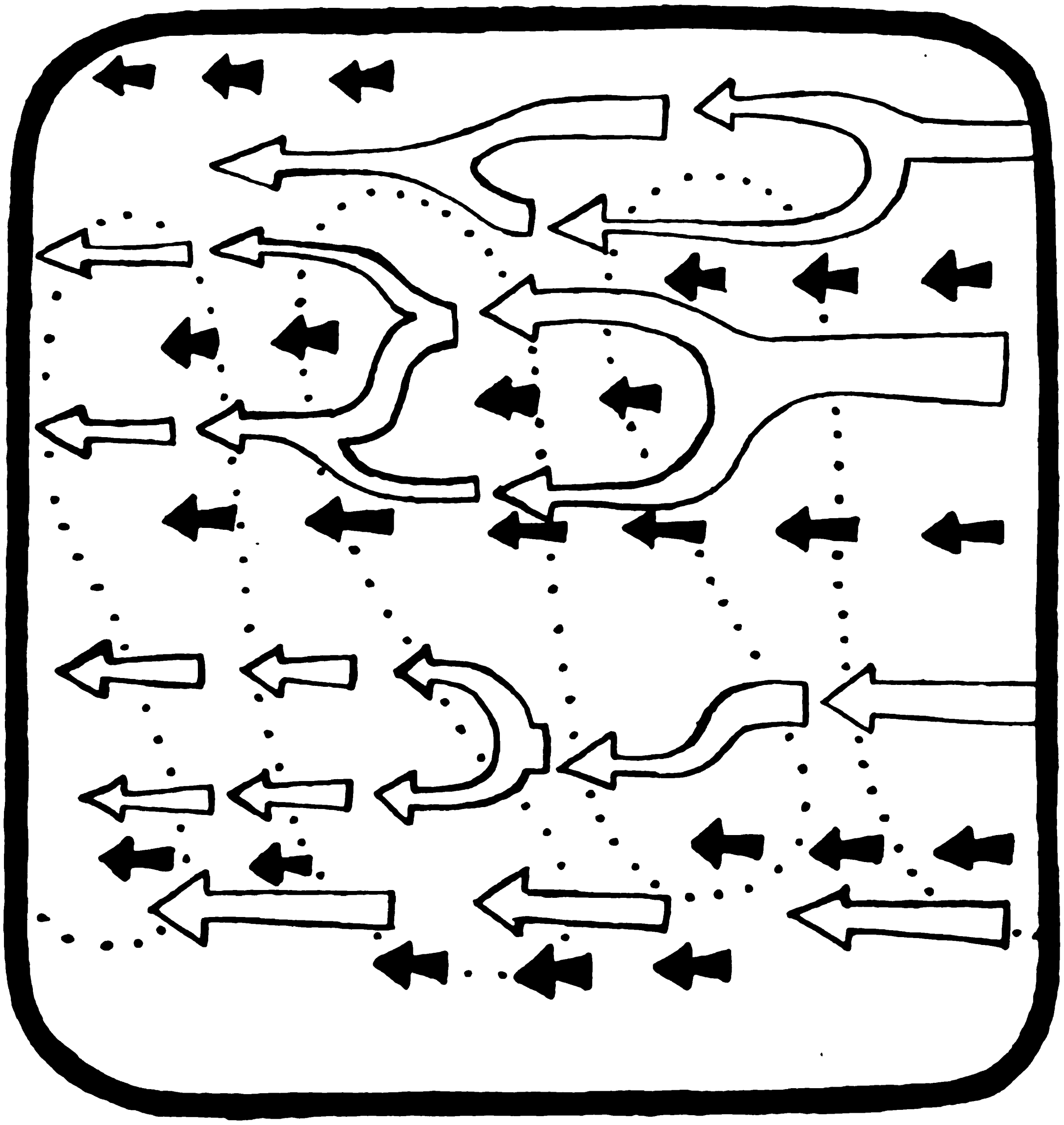

Figure 8. This is a schematic representation of the movement condition from the observer's standpoint. The observer is aware of vaguely defined shadows and bits of color which are in continual transit across the surface. Sometimes the things in transit undergo abrupt changes in color. The movement appears to be linear and constant.

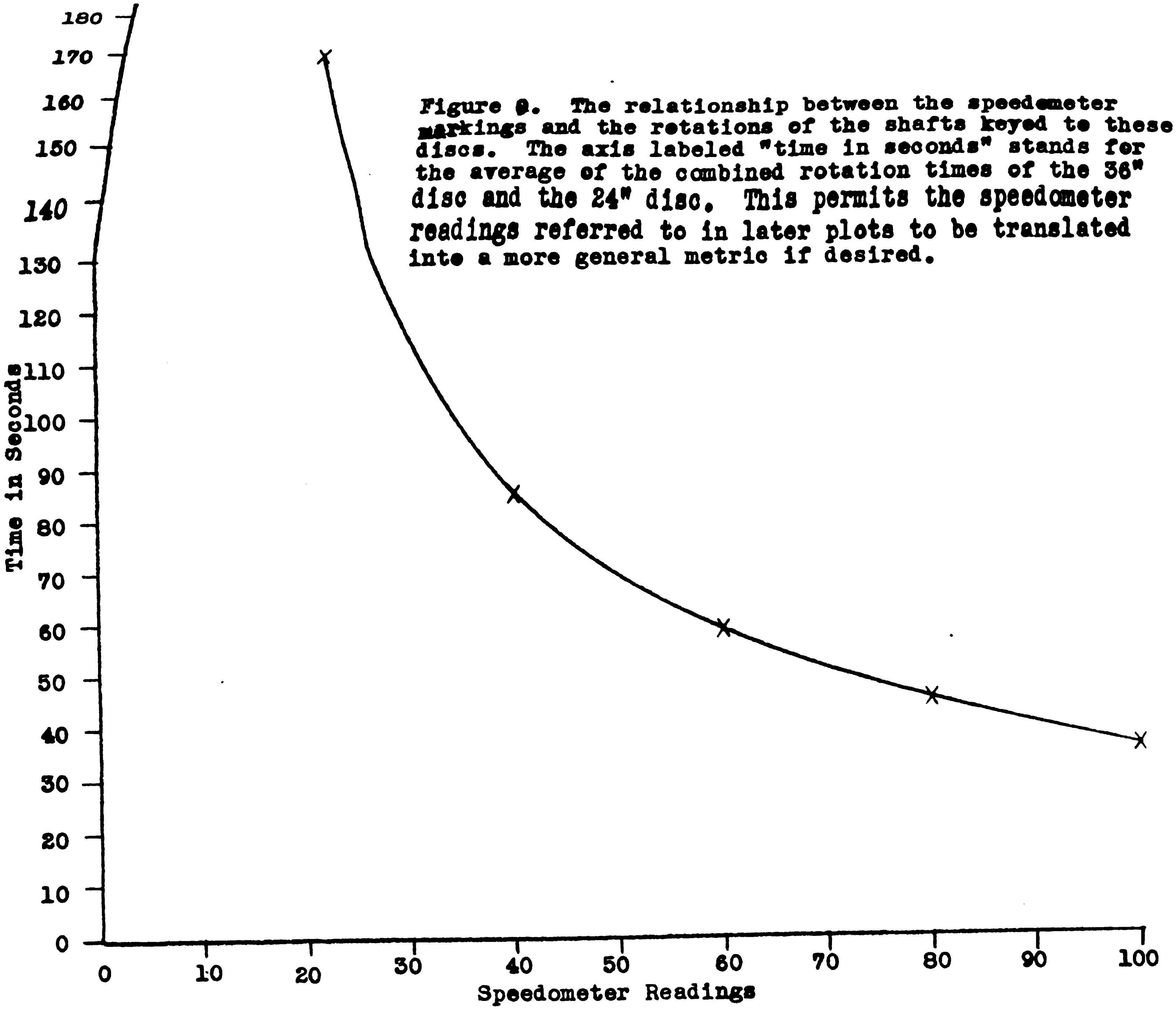

Figure 9. The relationship between the speedometer markings and the rotations of the shafts keyed to these discs. The axis labeled "time in seconds" stands for the average of the combined rotation times of the 36" disc and the 24" disc. This permits the speedometer readings referred to in later plots to be translated into a more general metric if desired.

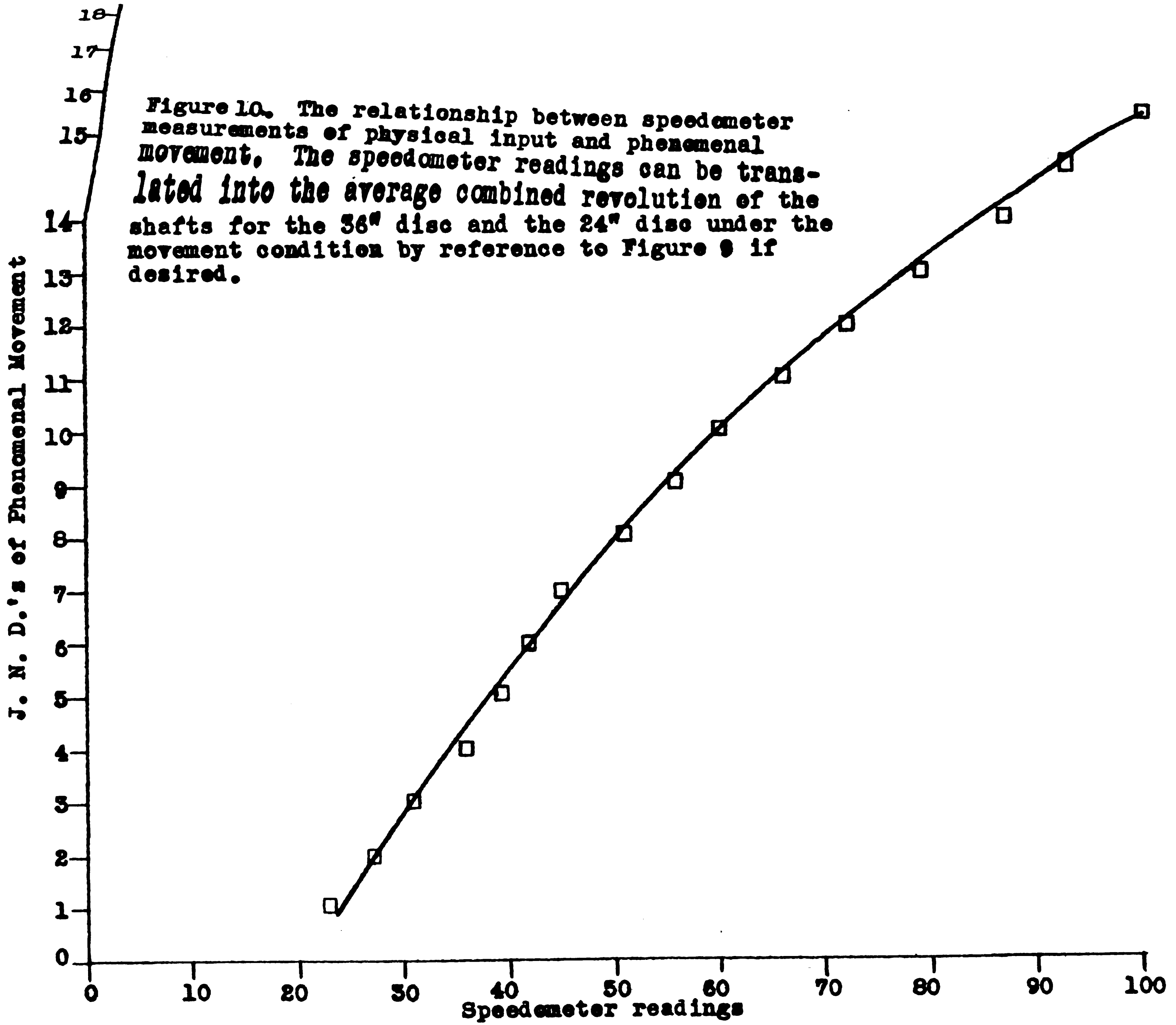

Figure 10. The relationship between speedometer measurements of physical input and phenomenal movement. The speedometer readings can be translated into the average combined revolution of the shafts for the 36" disc and the 24" disc under the movement condition by reference to Figure 9 if desired.

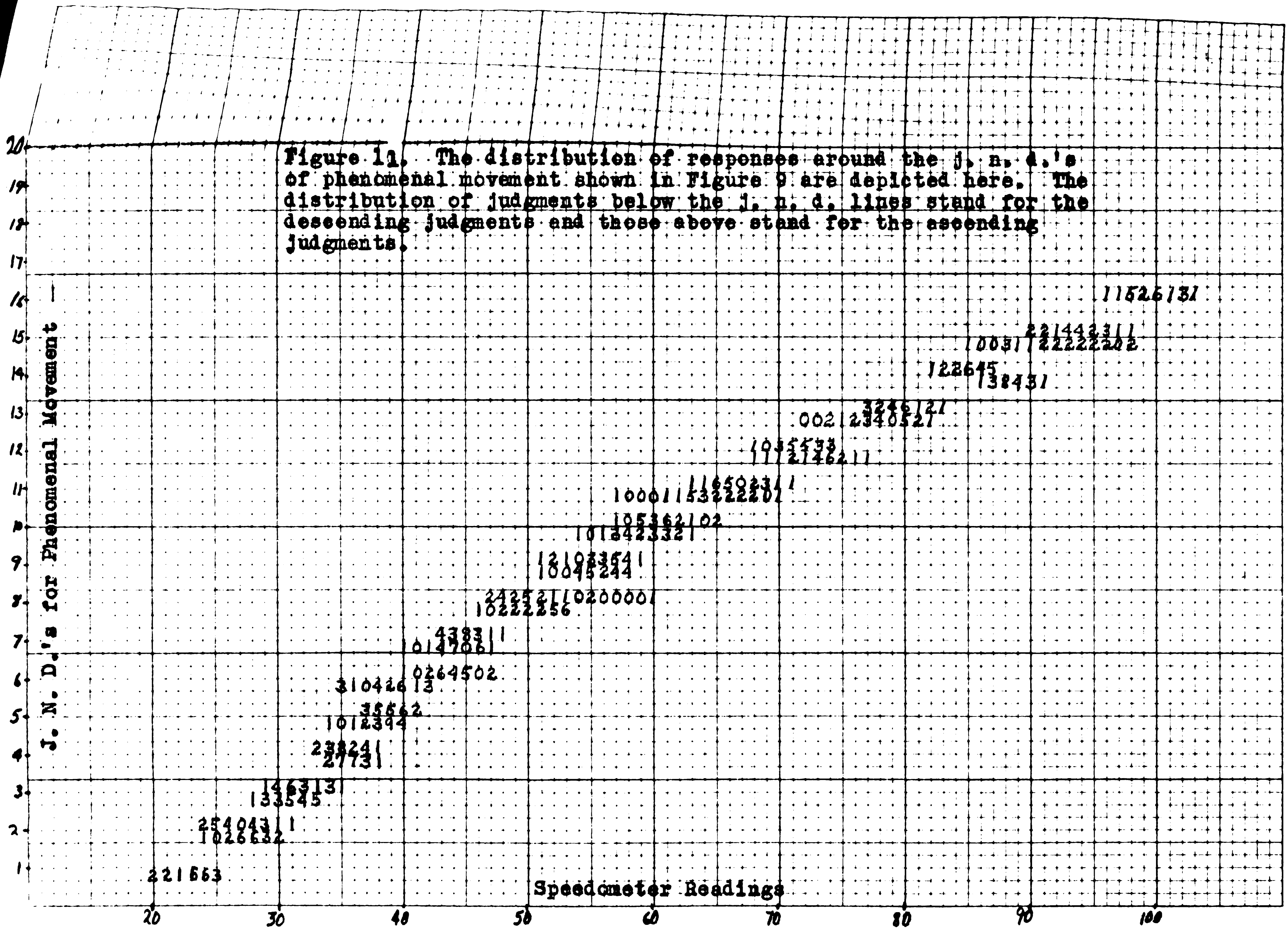

Figure 11. The distribution of responses around the j. n. d.'s of phenomenal movement shown in Figure 9 are depicted here. The distribution of judgments below the j. n. d. lines stand for the descending judgments and those above stand for the ascending judgments.

Selecting the Experimental Interval of Phenomenal Change

Experiment 3.

Purpose:

In later experiments we hope to relate phenomenal change and movement to the experience of duration. This will be attempted by means of systematic application of the method of comparison. Use of this method makes it necessary to choose an experimental standard--in this case a standard clock length interval to which the variable interval can be compared. From an experimental point of view, the ideally convenient interval for use would be: a) an interval where there would be no biasing of response; b) an interval in which there would be complete reliability of comparison; c) an interval sufficiently long to make manipulations of the experimental variables possible; and d) an interval not so long as to render the experiment impractically time consuming. Our first purpose is to establish the interval of minimal biasing.

The "indifference interval" might serve as one definition of minimal bias. This interval is defined as follows:

> "...that length of the variable at which the percentage of judgments meaning that the variable seems longer than the standard remains the same irrespective of the order in which the variable and standard are presented."[1]

1. H. Woodrow, "Time Perception," Handbook of Experimental Psychology ed. by S.E. Stevens (New York: John Wiley and Sons, Inc., 1951), p. 1225.

A fair amount of early "short duration" work was devoted toward discovery of this interval. Boring[2] reviewed the early experiments of Vierordt, Horning, Köllert, Estel and Mehner. They reported that identical auditory intervals ranging from a fraction of a second to several seconds showed an indifference interval at 0.7 seconds. Separately, Estel and Mehner in later researches employing a greater range of clock lengths also found periodic auditory indifference points although there was lack of agreement regarding the lengths of these periodicities. In contrast, Woodrow[3] has recently summarized experimental data in which no auditory indifference interval occurred and experimentation in which an order error opposite to that earlier reported occurs.[4] Moreover, other experimentation summarized by Woodrow[5] indicated that the physical characteristics of an interval are important determinants of the indifference interval.

It thus seems evident that prior experimentation can not be relied upon to provide an experimental interval of phenomenal change. An empirical answer specific to our phenomenal change condition is needed. Experiments 3,4,5,6 and

2. E.G. Boring. Sensation and Perception in the History of Experimental Psychology, (New York: D. Appleton-Century-Crofts Co., 1942), pp. 577-582.

3. H. Woodrow, "Time Perception," op. cit., p. 1227.

4. Time order errors in studies of "time perception" mean an effect due to the order of presentation of the standard and comparison intervals. With the procedure to be used in our experiment, the order is said to be "positive" when the variable is reported as shorter and "negative" when the variable is reported as longer and the intervals are identical in clock length.

5. H. Woodrow, "Time Perception," op. cit., p. 1227.

7 were designed to select a clock interval of minimal bias for use as the standard interval.

Subjects: Three subjects naive to the purposes of the experimentation were used. Two of the subjects, one male and one female, were college students. The other subject was a female in middle age.

Apparatus: The apparatus was set up for the change condition, as described in experiment 1. The only modification made consisted of the removal of the doorbell. The Burgess sprayer motor was used alone as a masking sound.

Method: The method of comparison was employed and the standard interval always occurred first. Three category comparisons were allowed. The experimenter attempted to allow 7 seconds between the comparison and standard intervals and to allow 15 seconds between the experimental pairs.

The standard and comparison intervals within each experimental pair were identical in all respects. The experimental pairs themselves varied with respect to clock length and rate of phenomenal change, however. With respect to clock length, there were 6 pairs at 5, 10, 15, 20, 25, 30, 40, 45, 60, 90, 120, 135, 180, 270, 390 and 600 seconds. With respect to rate of phenomenal change, eight presentations, each differing from the other in clock length, were made at the phenomenal change rates (See Figure 6) of 1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15 and 16.

Table 1 is a schematic representation of the method followed.

Procedure: The observer was seated in the viewing position. The following instructions were given:

> "We will start with the screen darkened. You are to watch the screen as it will become lighted. The screen when lighted will appear to change kaleidoscopically. You are to attend to the duration of this kaleidoscopic change. When the screen becomes dark again, this will be the signal that the standard interval has been concluded. When the screen becomes lighted again, this will be the signal that the second or comparison interval has begun. You will attend to this kaleidoscopic change just as you did in the first case. When the screen becomes dark again, this will be the signal that the second or comparison interval has just ended. At this point, you are to compare the second interval with the first and tell me whether the second was experienced by you as being "longer", "shorter", or "equal" to the first. Remember, I want you to judge the second relative to the first; if you make any other kind of comparison, do not fail to tell me."

After the formal directions were given, the task was discussed informally with the subject and any questions posed were answered. The experimenter emphasized to the subject informally that the task of comparison was probably going to be difficult from the subject's point of view. The subject was warned against using any secondary criterion, such as counting, listening to his pulse or looking at his watch. The subjects were also discouraged from using the equal category to express "uncertainty". It was strongly emphasized that a response of "equal" is just as much a comparison as responses of "longer" and "shorter". No subject served longer than 50 minutes without a break.

Table 1

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT 3

Rate of phen. chnge	Standard	1	2	4	5	6	7	8	10	11	12	14	15	16	total cases
	Comparison	1	2	4	5	6	7	8	10	11	12	14	15	16	
length of intervals in seconds	Stand.	5												5	
	Comp.	5												5	
	cases	3												3	6
	Stand.		10										10		
	Comp.		10										10		
	cases		3										3		6
	Stand.			15								15			
	Comp.			15								15			
	cases			3								3			6
	Stand.				20						20				
	Comp.				20						20				
	cases				3						3				6
	Stand.					25				25					
	Comp.					25				25					
	cases.					3				3					6
	Stand.						30		30						
	Comp.						30		30						
	cases						3		3						6
	Stand.	40												40	
	Comp.	40												40	
	cases	3												3	6
	Stand.		45										45		
	Comp.		45										45		
	cases.		3										3		6
	Stand.			60								60			
	Comp.			60								60			
	cases.			3								3			6
	Stand.				90						90				
	Comp.				90						90				
	cases.				3						3				6
	Stand.					125				125					
	Comp.					125				125					
	cases.					3				3					6
	Stand.						130		130						
	Comp.						130		130						
	cases.						3		3						6
	Stand.						180	180							
	Comp.						180	180							
	cases.						3	3							6
	Stand.							270	270						
	Comp.							270	270						
	cases							3	3						6

(continued on the following page)

Table 1 (continued)

rate of phen. chnge	Standard	1	2	4	5	6	7	8	10	11	12	14	15	16	total cases
	Comparison	1	2	4	5	6	7	8	10	11	12	14	15	16	
	Stand.	390												390	
	Comp.	390												390	
	cases.	3												3	6
	Stand.		600										600		
	Comp.		600										600		
	cases.		3										3		6
Total	Cases	9	9	6	6	6	9	6	9	6	6	6	9	9	96/ / 96

<u>Results</u>: In Figure 12, the average response at each time level is depicted. The responses were averaged by assigning each "equal" response a weight of two hundred, each "shorter" response a weight of one hundred and each "longer" response a weight of three hundred. The function does not show a single indifference point although a trend toward "longer" comparisons as the interval increases in length is evident. In Figure 13, the judgments are plotted separately. It can be seen from Figure 13 that, no matter what range of clock lengths were used, the comparison intervals were consistently experienced as being longer than the standard. Somewhere between 60 and 135 seconds this tendency becomes very marked, the "longer" comparisons outweighing the other categories twice over. It can also be observed that the "equal" and "shorter" comparisons decrease while the "longer" comparisons increase as a function of clock length.

Two subjects reported that they were unable to use the first interval as the standard. They reported that the second by reason of its "freshness" always asserted itself so as to render the prior duration a comparison duration. The procedure was modified to accomodate their habit.

<u>Conclusions</u>: No single indifference point such as Vierordt found when he used intervals ranging from 0.3 to 1.4 seconds occurred when clock lengths varying from 5 to 600 seconds were used. Neither does there seem to be a single place

on the continuum where errors change from positive to negative. The findings indicate that as the experimental intervals become longer in clock time (plus 180 seconds) the comparison interval was with increasing frequency experienced as being longer than the standard. The results thus indicate that clock lengths of plus 180 seconds are to be avoided in research relating rates of phenomenal change to phenomenal duration.

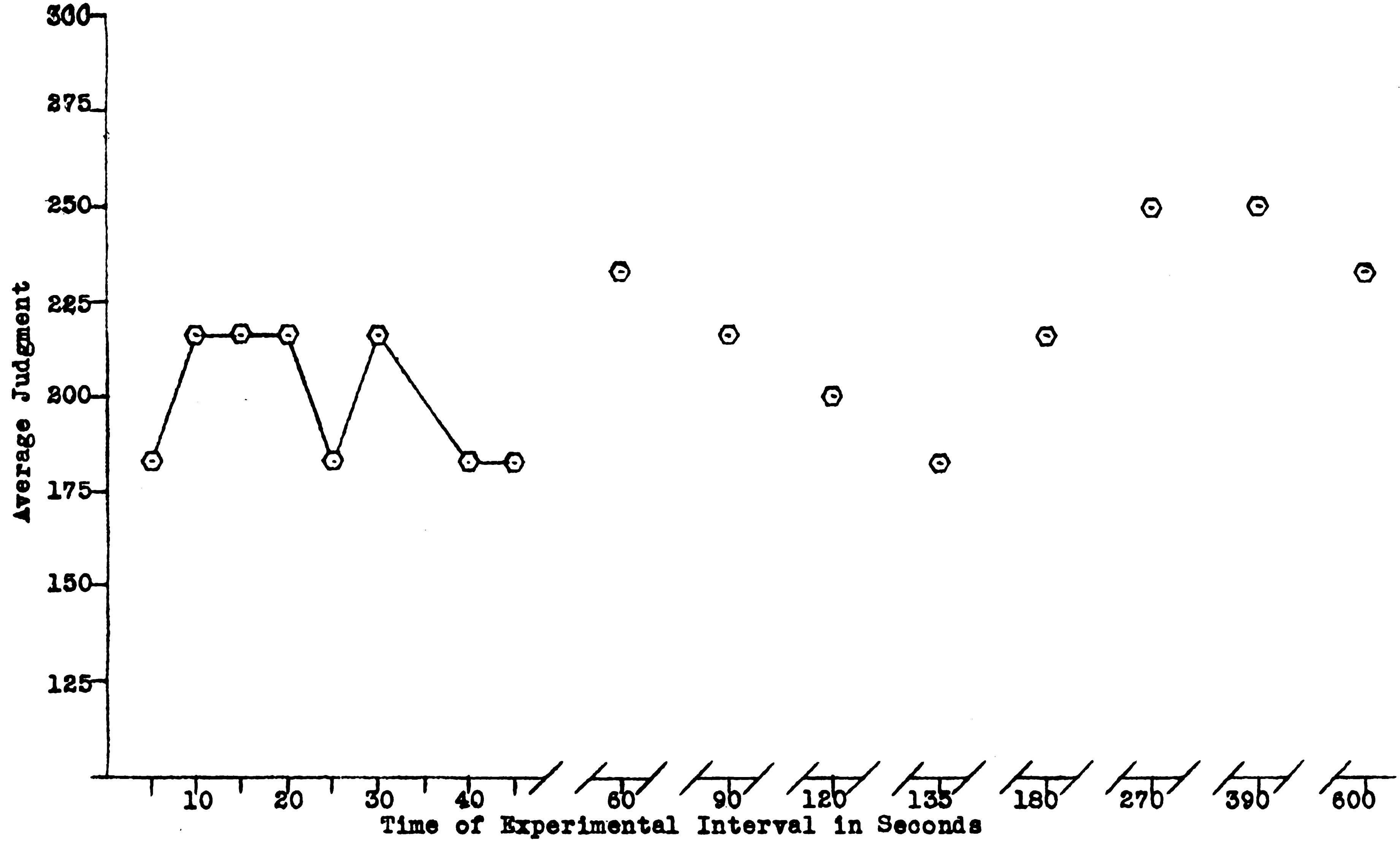

Figure 12. The relationship between judgments of the phenomenal durations of phenomenal changes and the clock lengths employed experimentally. Each point plotted represents the mean of 6 comparisons. The standard and comparison intervals were all equal in clock length and the phenomenal change rate remained constant throughout each experimental presentation.

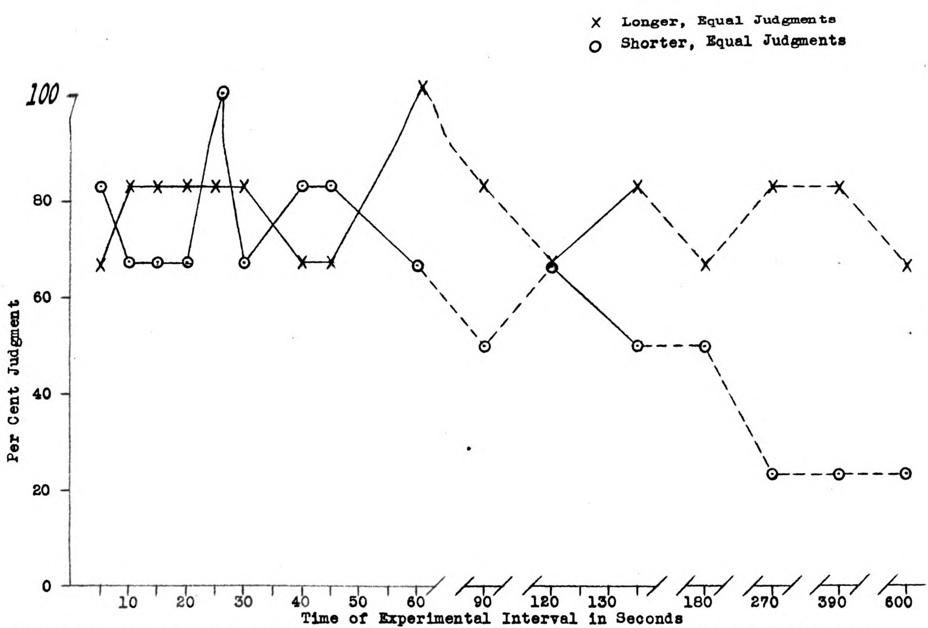

Figure 13. Three category judgments when phenomenal change of various clock lengths were employed. 6 comparisons were made for each time length; standard and comparison intervals were equal in clock length. The phenomenal change rate was constant for each experimental pair presented.

Experiment 4.

Experiment 4 is an extension of experiment 3. It is a further attempt to select a clock length for use as the standard interval in later experimentation involving the experienced endurance of phenomenal change.

Subjects: Nine college students were used as subjects. Seven were male and two female. All were naive respecting the purposes of experimentation.

Apparatus: The apparatus is identical to that described for experiment 3.

Method: The method of comparison was employed with the standard interval always being presented first. Three category comparisons were allowed. The experimenter allowed 7 seconds between the standard and comparison intervals and 15 seconds between pairs.

The standard and comparison intervals within each pair presented were identical with respect to clock length. The pairs themselves differed from the standard to the comparison interval. Thus, the experimental pairs varied in clock length from 10 to 600 seconds. The standard and comparison intervals were 10, 15, 30, 60, 180, 390 or 600 seconds in clock length with 18 comparisons being made at each interval. With respect to the phenomenal change differences, the phenominal change rate of the standard (See Figure 6) was 2 and the comparison 12, the standard 7 and the comparison 12, the standard 2 and the comparison 7, the standard 12 and the comparison 2, the standard 12 and the comparison 7, and the standard 7 and the comparison 2 for 21 pairs each. In making the manipulations of phenomenal change just described, 63 experimental pairs occurred in which a more rapid phenomenal change occurred in the comparison than occurred in the standard, and 63 cases in which the opposite was true. Also, this method produced 42 pairs which were altered 12 points and 84 pairs which were altered 6 points up or down from the standard to the comparison interval. A total of 126 comparisons were made in all. Table 2 provides a schematic representation of the method followed.

Procedure: The procedure was identical to that followed in experiment 3.

Results: Figure 18 is a plot of the comparisons made when the rate of the comparison interval was lowered from standard to comparison. Figure 19 contains the data for the raised rate. All the comparisons made in experiment 4 plus the comparisons of experiment 3 made using the experimental intervals of 4 are plotted in Figure 14.

Table 2

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT.4

Length of intervals in secs.	Standard Comparison	10 10	15 15	30 30	60 60	180 180	390 390	600 600	total cases
Rate of phenomenal change	Stand.	2	2	2	2	2	2	2	
	Comp.	7	7	7	7	7	7	7	
	cases.	3	3	3	3	3	3	3	12
	Stand.	2	2	2	2	2	2	2	
	Comp.	12	12	12	12	12	12	12	
	cases.	3	3	3	3	3	3	3	12
	Stand.	7	7	7	7	7	7	7	
	Comp.	12	12	12	12	12	12	12	
	cases.	3	3	3	3	3	3	3	12
	Stand.	7	7	7	7	7	7	7	
	Comp.	2	2	2	2	2	2	2	
	cases.	3	3	3	3	3	3	3	12
	Stand.	12	12	12	12	12	12	12	
	Comp.	2	2	2	2	2	2	2	
	cases.	3	3	3	3	3	3	3	12
	Stand.	12	12	12	12	12	12	12	
	Comp.	7	7	7	7	7	7	7	
	cases.	3	3	3	3	3	3	3	12
Total cases............		18	18	18	18	18	18	18	126/126

Several things are evident from these three figures. First, it is impossible to assign an "indifference point" in the sense the term was originally employed. Second, the interval of least bias seems to lie around the 60 second clock length. Third, the general decline of both functions on each graph indicates that the frequency of equal comparisons decreases as the experimental interval increases in clock length. Fourth, the longer comparisons increase relative to the shorter comparisons as the interval clock length increases. Fifth, the longer and shorter functions cross somewhere between the 30 and 180 second intervals and biasing becomes distinctly in the direction of a comparison of longer.

Conclusions: It will not be possible to use the "indifference interval" as the standard interval in the later phenomenal duration experiments. No such interval has been found. The intervals functioning most like the "indifference interval" occurred within the 60 to 180 second range, i.e. within this range the time order errors changed from positive to negative. Apparently it will be necessary to select a standard interval from within this range. The interval selected should be that interval showing minimal bias.

Experiments 5, 6 and 7.

Purpose: Experiments 3 and 4 have indicated that all intervals which are sufficiently long to make manipulations of experimental variables possible have constant errors. These experiments also indicate, however, that the biasing due to purely procedural characteristics will be minimal around an interval of 60 seconds. Bearing this finding in mind, experiments 5, 6 and 7 were designed to select a definite experimental interval of phenomenal change for use in the study of duration. Specifically, these three experiments aim to determine which of three possible experimental intervals, 30, 90 or 180 seconds, will yield the greatest reliability of comparison.

Subjects: In experiment 5, 12 subjects were used; 3 were female and 9 male. In experiment 6, 12 subjects were used, 3 female and 9 male. In experiment 7, 4 subjects were used, 2 female and 2 male.

Apparatus: The apparatus was unchanged from that previously described for experiment 3.

Method: The method of comparison was employed with the standard interval always occurring first. Three category comparisons were allowed. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between experimental pairs.

The standard and comparison intervals of each pair presented in experiments 5, 6 and 7 were identical as regards phenomenal change. The standard and comparison intervals differed from one another as regards their clock lengths, however. In experiment 5, a 30 second interval was made 0, 5, 8, 11, 14, 17, 20, 23, 26 or 29 percent longer or shorter than the standard interval. In the experiment, a total of 250 observations were made with an equal number of comparisons occurring at every interval excepting the 26 and 29 percent levels. At the 26 and 29 percent levels, it was not necessary to take as many observations since there was almost no variability of comparison. Experiment 6 was identical to experiment 5 except that a standard interval of 90 seconds was employed.

In experiment 7, a 180 second interval was used as a standard while the comparison intervals were 0, 5, 8, 11, 14, 17, 20 or 23 percent longer or shorter than the standard interval. A total of 96 observations were taken at the 180 second interval with equal observations occurring for each experimental pair presented. The pairs were randomly presented in each experiment.

Tables 3, 4, and 5 represent a schematic representation of the method followed.

Table 3

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT 5

Rate of Phenomenal Change	Standard	2	7	12	Total cases
	Comparison	2	7	12	
Length of Intervals in Seconds	Standard	30	30	30	
	Comparison	+29%*	+29%	+29%	
	cases	3	4	3	10
	Standard	30	30	30	
	Comparison	+26%	+26%	+26%	
	cases	3	4	3	10
	Standard	30	30	30	
	Comparison	+23%	+23%	+23%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+20%	+20%	+20%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+17%	+17%	+17%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+14%	+14%	+14%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+11%	+11%	+11%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+ 8%	+8%	+8%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	+5%	+5%	+5%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	0%	0%	0%	
	cases	5	4	5	14

Table 3 (Continued)

Rate of phenomenal change	Standard / Comparison	2 / 2	7 / 7	12 / 12	Total cases
Length of intervals in seconds	Standard	30	30	30	
	Comparison	-5%	-5%	-5%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-8%	-8%	-8%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-11%	-11%	-11%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-14%	-14%	-14%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-17%	-17%	-17%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-20%	-20%	-20%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-23%	-23%	-23%	
	cases	5	4	5	14
	Standard	30	30	30	
	Comparison	-26%	-26%	-26%	
	cases	3	4	4	10
	Standard	30	30	30	
	Comparison	-29%	-29%	-29%	
	cases	3	4	3	10
Total cases.......		87	76	87	250/250

* The comparison intervals are expressed in terms of percent longer or shorter than the standard.

Table 4

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT 6

Rate of phenomenal change	Standard / Comparison	2 / 2	7 / 7	12 / 12	total cases
Length of intervals in seconds	Standard	90	90	90	
	Comparison	+29%	+29%	+29%	
	cases	3	4	3	10
	Standard	90	90	90	
	Comparison	+26%	+26%	+26%	
	cases	3	4	3	10
	Standard	90	90	90	
	Comparison	+23%	+23%	+23%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+20%	+20%	+20%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+17%	+17%	+17%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+14%	+14%	+14%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+11%	+11%	+11%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+8%	+8%	+8%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	+5%	+5%	+5%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	0%	0%	0%	
	cases	5	4	5	14

Table 4 (Continued)

Rate of phenomenal change	Standard / Comparison	2 / 2	7 / 7	12 / 12	total cases
Length of intervals in seconds	Standard	90	90	90	
	Comparison	-5%	-5%	-5%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-8%	-8%	-8%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-11%	-11%	-11%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-14%	-14%	-14%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-17%	-17%	-17%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-20%	-20%	-20%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-23%	-23%	-23%	
	cases	5	4	5	14
	Standard	90	90	90	
	Comparison	-26%	-26%	-26%	
	cases	3	4	3	10
	Standard	90	90	90	
	Comparison	-29%	-29%	-29%	
	cases	3	4	3	10
total cases		87	76	87	250/250

Table 5

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT 7

rate of phenomenal change					total cases
	Standard	2	7	12	
	Comparison	2	7	12	
Length of intervals in seconds	Standard	180	180	180	
	Comparison	+23%*	+23%	+23%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+20%	+20%	+20%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+17%	+17%	+17%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+14%	+14%	+14%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+11%	+11%	+11%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+8%	+8%	+8%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	+5%	+5%	+5%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	0%	0%	0%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	-5%	-5%	-5%	
	cases	4	4	4	12
	Standard	180	180	180	
	Comparison	-8%	-8%	-8%	
	cases	4	4	4	12

Table 5 (Continued)

rate of phenomenal change	Standard / Comparison	2 / 2	7 / 7	12 / 12	total cases
Length of intervals in seconds.	Standard	180	180	180	
	Comparison	-11%	-11%	-11%	
	cases.	4	4	4	12
	Standard	180	180	180	
	Comparison	-14%	-14%	-14%	
	cases.	4	4	4	12
	Standard	180	180	180	
	Comparison	-17%	-17%	-17%	
	cases.	4	4	4	12
	Standard	180	180	180	
	Comparison	-20%	-20%	-20%	
	cases.	4	4	4	12
	Standard	180	180	180	
	Comparison	-23%	-23%	-23%	
	Cases	4	4	4	12
total cases		60	60	60	180/180

* the comparison intervals are expressed in terms of percentage longer or shorter than the standard.

Procedure: The procedure followed was exactly the same as that employed in experiment 3.

Results: The results from experiment 5 are depicted in Figure 15. The functions plotted in this figure are irregular in direction and the comparisons do not follow the temporal values in a predictable manner. Phenomenal equality occurs at a number of points that are quite widely separated. Since 250 observations were made, these features probably can not be accounted for in terms of the sample.

Figure 16 shows a plot of the data yielded by experiment 6. Although equal numbers of judgments were made and there was a large overlap of subjects, the irregularities of figure 15 are considerably lessened. The comparisons follow the temporal values in a regular way. Phenomenal equality is a point and not a zone on the clock length continuum. The point where the curves cross indicates that the comparison interval need only be 94% of the clock length of the standard interval to be experienced as equal.

The data from experiment 7 is plotted in Figure 17. This data is plotted against clock time and the result is an irregular function. Several points of phenomenal equality are evident. The zone of equality occurs farther toward the longer end of the clock length continuum than is the case for the 30 second interval.

<u>Conclusions</u>: The 90 second interval produced a point and not a zone of phenomenal equality, and this length interval did not produce periodic reversals of the psychophysical functions. The 90 second interval seems to be superior to the 30 and 180 second intervals for experimental use.

The results indicate that the experimenter can expect a slight biasing of comparisons in favor of longer comparisons when a 90 second standard is used.

Experiments 5, 6 and 7 conform the findings of experiments 3 and 4. As the clock time of the experimental interval was increased, comparisons of "longer" increased in frequency in all five experiments.

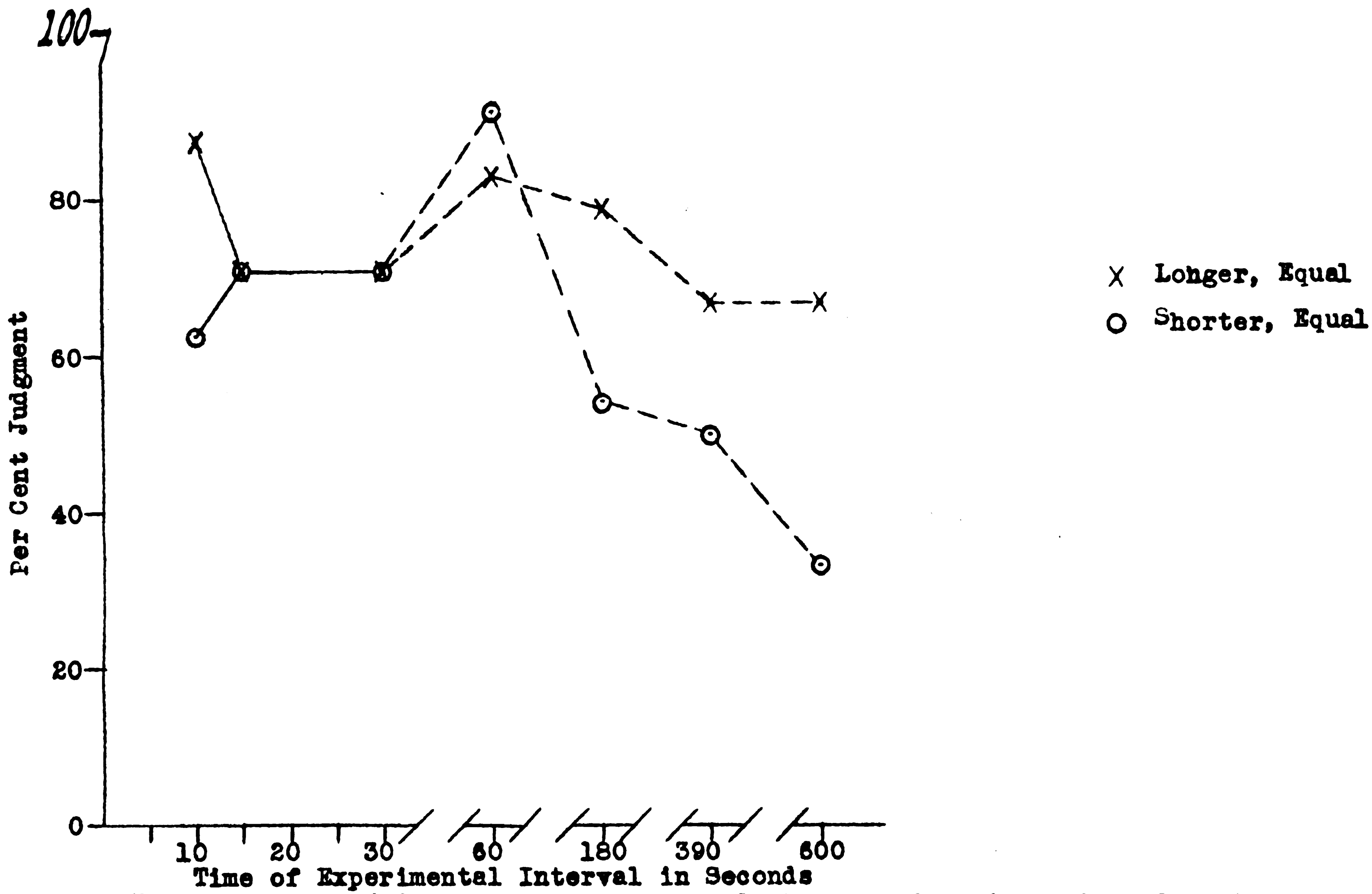

Figure 14. Three category judgments when phenomenal changes of various clock lengths are experimentally employed. 24 comparisons were made for each time length; standard and comparison intervals were equal in clock length. The phenomenal change rate was constant from standard to comparison interval for 6 of the 24 comparisons, decreased for 9 of the trials, and increased for 9.

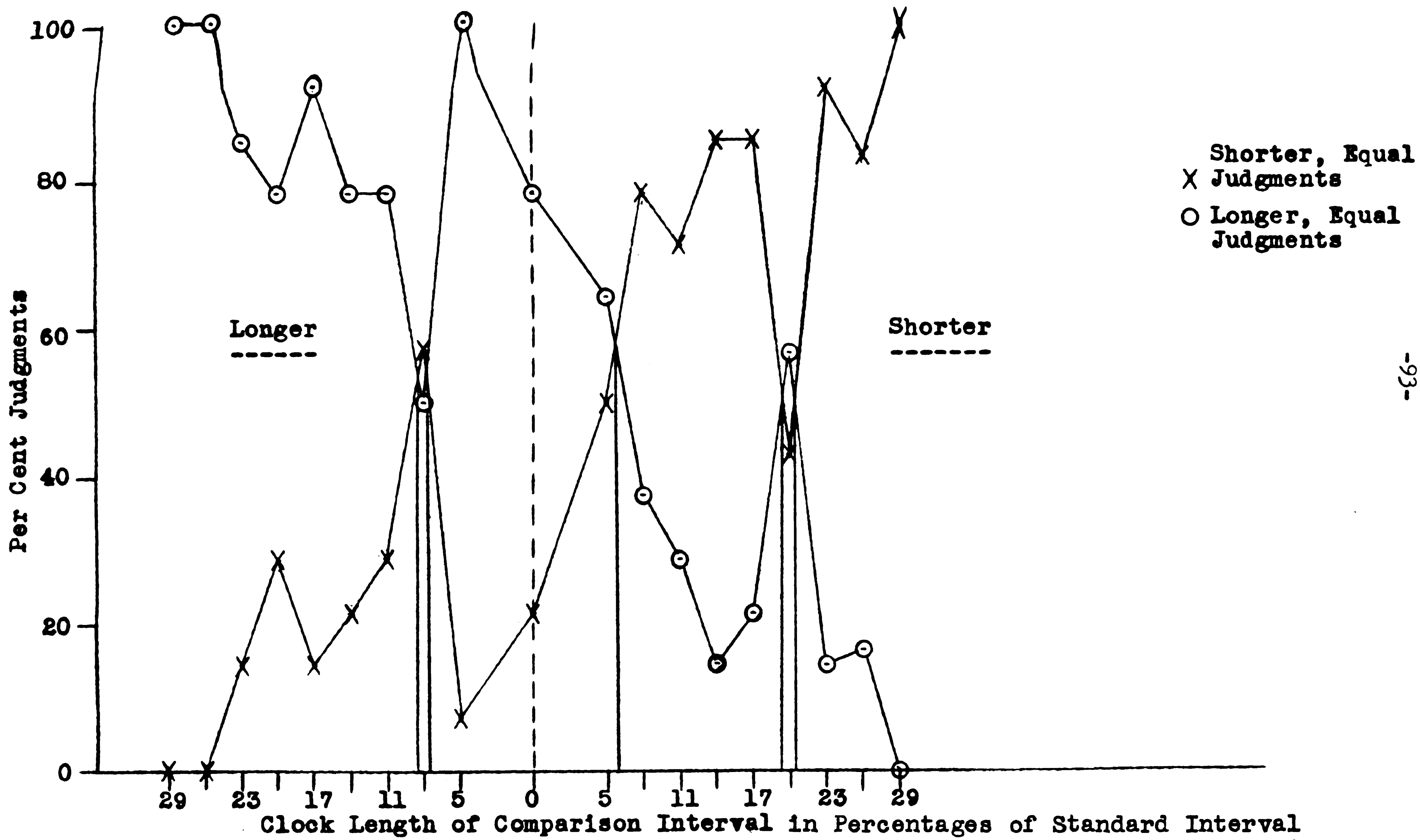

Figure 15. The standard phenomenal change interval was set at thirty seconds and the comparison phenomenal change interval varied in clock length. The phenomenal change rate was held constant experimentally during both the standard and comparison intervals. 250 comparisons were made to fix the function.

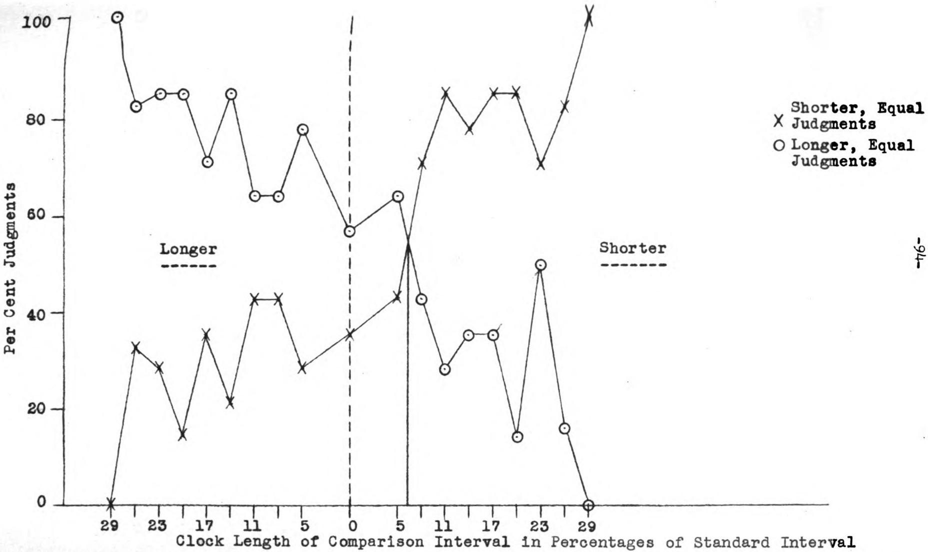

Figure 16. The standard phenomenal change interval was set at 90 seconds and the comparison phenomenal change interval varied in clock length. The phenomenal change rate was held constant experimentally during both the standard and comparison intervals. 250 comparisons were made to fix the function.

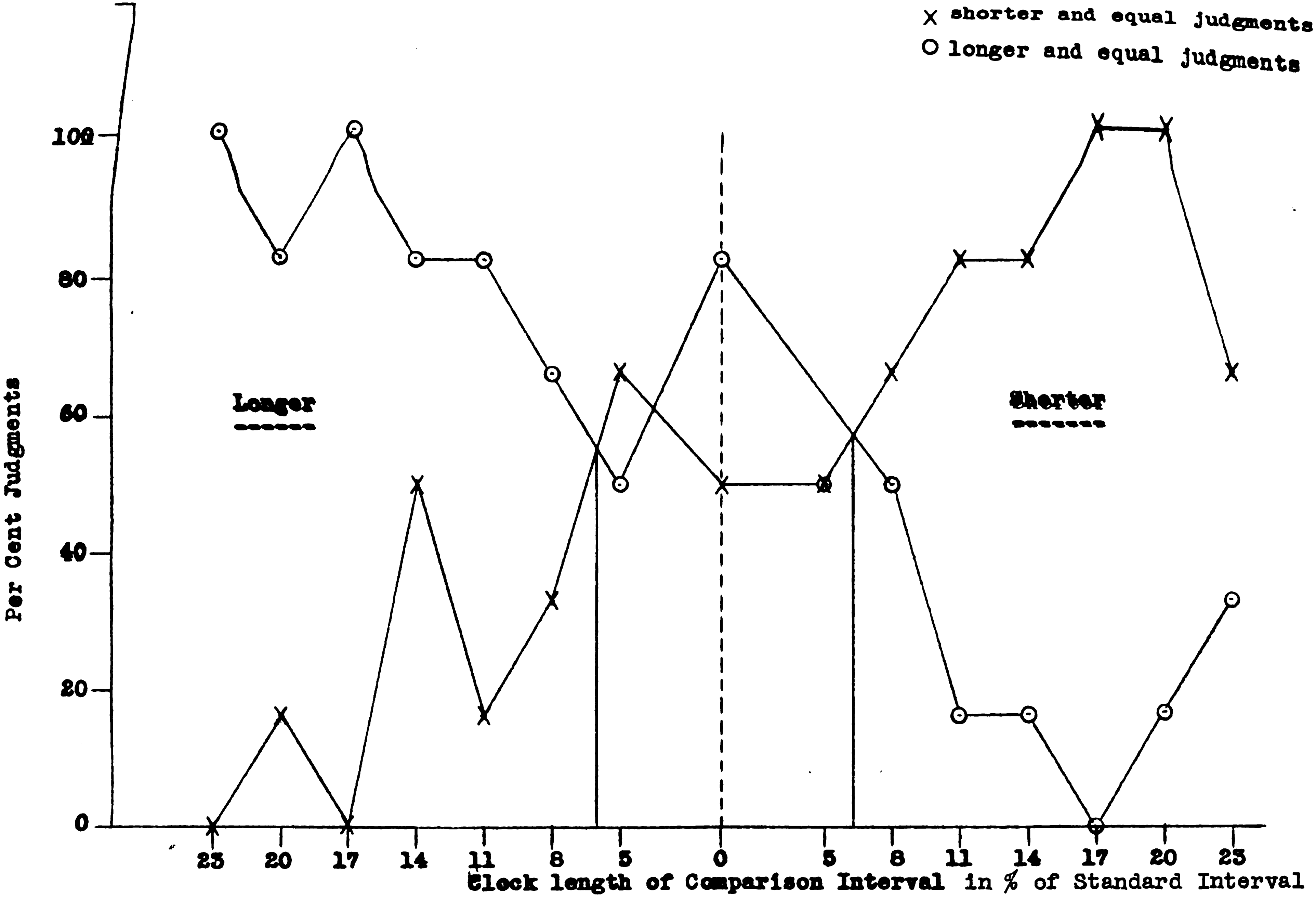

Figure 17. The standard phenomenal change interval was set at 180 seconds and the comparison phenomenal change interval varied in clock length. The phenomenal change rate was held constant experimentally during both the standard and comparison intervals. 96 comparisons were made to fix the function.

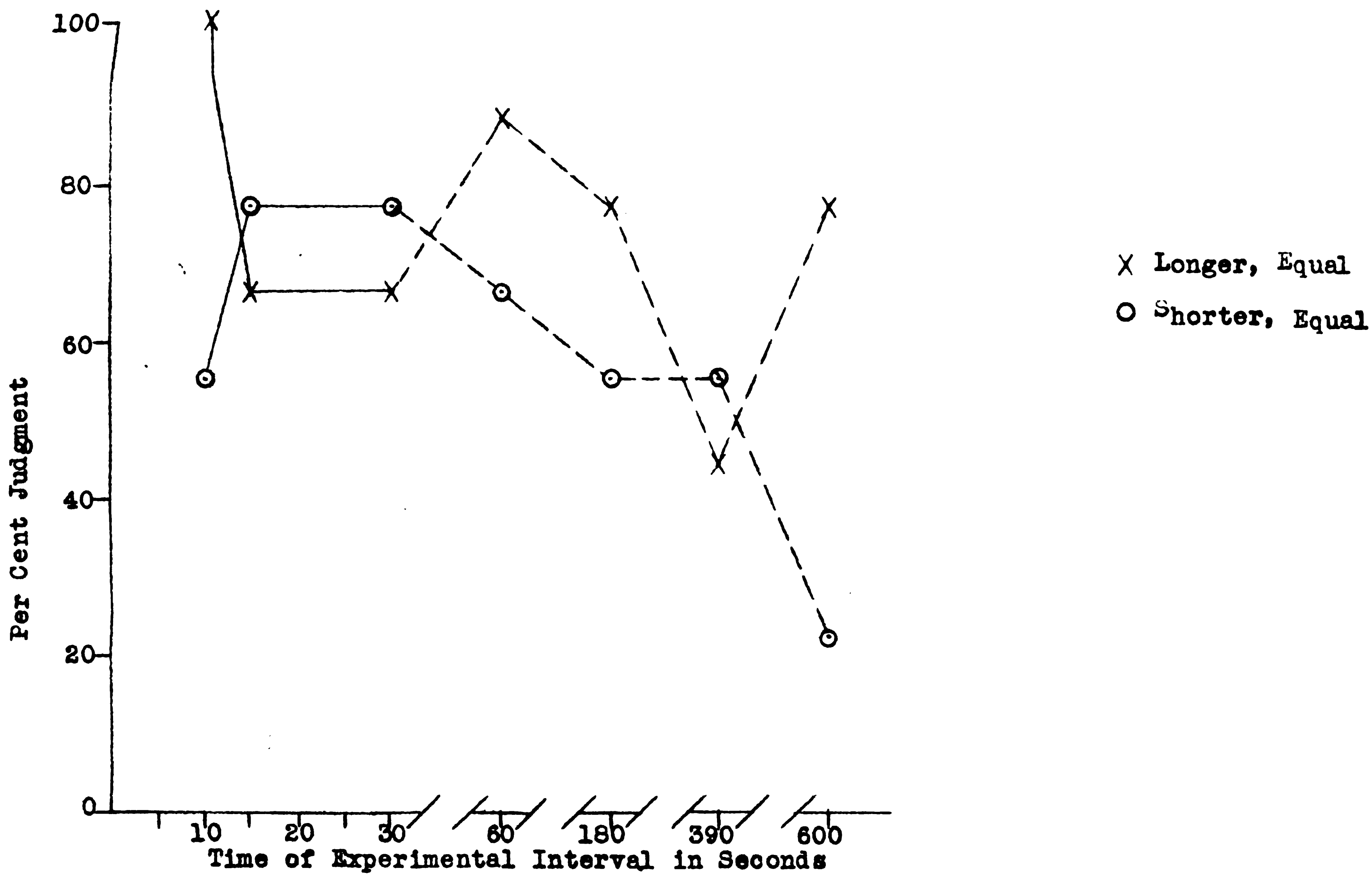

Figure 18. Three category judgments when phenomenal changes of various clock lengths were employed. 9 comparisons were made at each clock length; standard and comparison intervals were equal in clock length. The rate during the comparison interval was a steady 5 or 10 points below the standard phenomenal change scale rate.

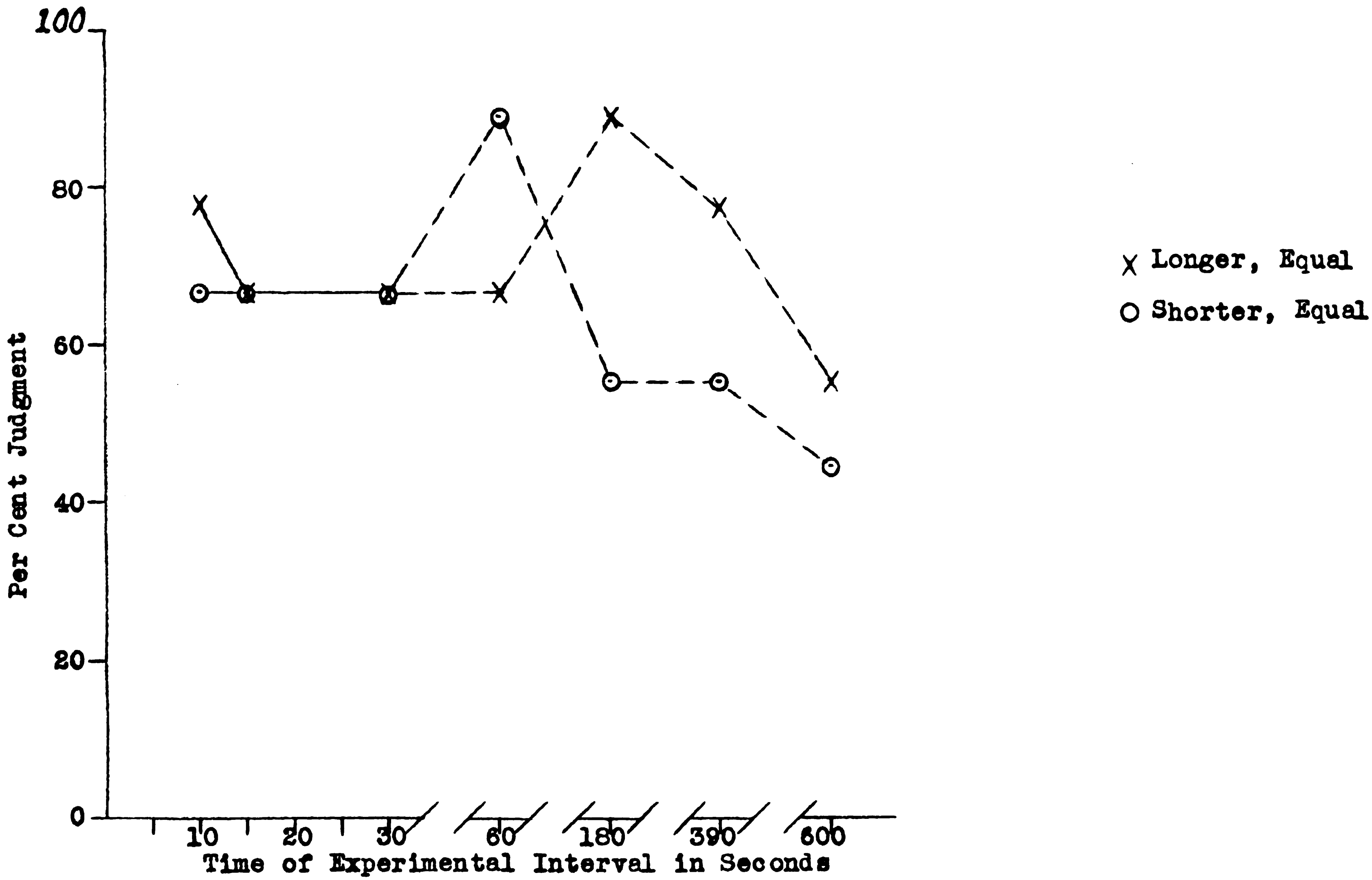

Figure 19. Three category judgments when phenomenal changes of various clock lengths were employed. 9 comparisons were made for each time length; standard and comparison intervals were equal in clock length. The rate during the comparison interval was a steady 5 or 10 points above the standard phenomenal change scale rate.

The Experienced Endurance of Various Phenomenal Changes Maintaining a Constant Cadence

Experiment 8.

Purpose: The data from experiment 4 suggest that the rate at which phenomenal events change have an effect upon the experience of duration. The different rates of change have produced differences in overall variability and have produced differences in the distribution of judgments of both extremes. It can also be seen from Figures 18 and 19 that there is a relationship between various rates of phenomenal change and the frequency of occurrence of various comparison responses. The purpose of experiment 8 is to investigate the relationship between various rates of phenomenal change previously scaled and the experience of duration.

Subjects: Six subjects were used, 4 male and 2 female. All subjects were college students and all were naive respecting the aims of experimentation.

Apparatus: The apparatus was identical with that employed in experiment 3.

Method: The method of comparison was employed, and the standard interval always occurred first. The clock length of the standard was always 90 seconds. Three

category judgments were allowed. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between experimental pairs.

The standard and comparison intervals of each pair differed as regards the rate of phenomenal change and as regards clock length. With respect to phenomenal change, the following variations were made. A total of 270 comparisons were made when the comparison exceeded the standard in change rate; specifically, 90 presentations were made with the standard at phenomenal change 2 (See Figure 6) and the comparison at phenomenal change 12, 90 presentations were made with the standard at 2 and the comparison at 7, 90 presentations with the standard at 7 and the comparison at 12. Another 270 comparisons were made when the opposite was the case, when the standard exceeded the comparison in change rate. Specifically, 90 presentations were made with the standard at phenomenal change 12 and the comparison at phenomenal change 2; 90 presentations with the standard at phenomenal change 12 and the comparison at 7; and 90 presentations with the standard at 7 and the comparison at 2. With respect to clock length, the following differences were present. The clock length of the comparison interval was 0,5,8,11,14,17,20 or 23% longer or shorter than the standard interval.

All 540 presentations were made according to a random plan. Table 6 is a schematic representation of the method employed.

Table 6

Rate of phenomenal change.	Standard / Comparison	2 / 2	2 / 2	7 / 7	7 / 7	12 / 12	12 / 12	total cases
Length of intervals in seconds	Stan.	90	90	90	90	90	90	
	Comp.	+23%*	+23%	+23%	+23%	+23%	+23%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+20%	+20%	+20%	+20%	+20%	+20%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+17%	+17%	+17%	+17%	+17%	+17%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+14%	+14%	+14%	+14%	+14%	+14%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+11%	+11%	+11%	+11%	+11%	+11%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+8%	+8%	+8%	+8%	+8%	+8%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	+5%	+5%	+5%	+5%	+5%	+5%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	0%	0%	0%	0%	0%	0%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-5%	-5%	-5%	-5%	-5%	-5%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-8%	-8%	-8%	-8%	-8%	-8%	
	cases.	6	6	6	6	6	6	36

Table 6 (Continued)

Rate of phenomenal change	Standard / Comparison	2 / 2	2 / 2	7 / 7	7 / 7	12 / 12	12 / 12	total cases
Length of intervals in seconds	Stan.	90	90	90	90	90	90	
	Comp.	-11%	-11%	-11%	-11%	-11%	-11%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-14%	-14%	-14%	-14%	-14%	-14%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-17%	-17%	-17%	-17%	-17%	-17%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-20%	-20%	-20%	-20%	-20%	-20%	
	cases.	6	6	6	6	6	6	36
	Stan.	90	90	90	90	90	90	
	Comp.	-23%	-23%	-23%	-23%	-23%	-23%	
	cases.	6	6	6	6	6	6	36
total cases....		90	90	90	90	90	90	540/540

* The comparison intervals are expressed in terms of percentage longer or shorter than the standard.

Procedure: The procedure was the same as that employed in experiment 3.

Results: Figure 20 shows the results when the rate of phenomenal change was slower in the standard than in the comparison intervals. Figure 21 shows the results when the opposite was true. Both figures are clearly different with respect to the point of phenomenal equality. When the rate of phenomenal change was increased, the point of equality fell on the long side of the graph. When the conditions were exactly reversed we find that the comparison had to be made about 7% shorter than the standard if it was to be experienced as having an equal phenomenal duration.

Conclusions: The experiment clearly shows that phenomenal duration is determined in part by phenomenal change. The results show that rapid phenomenal changes lead to longer phenomenal durations than do slow changes. The experiment indicates also that we have a way to vary the phenomenal duration of an event in a controlled fashion while holding the clock time of that event constant.

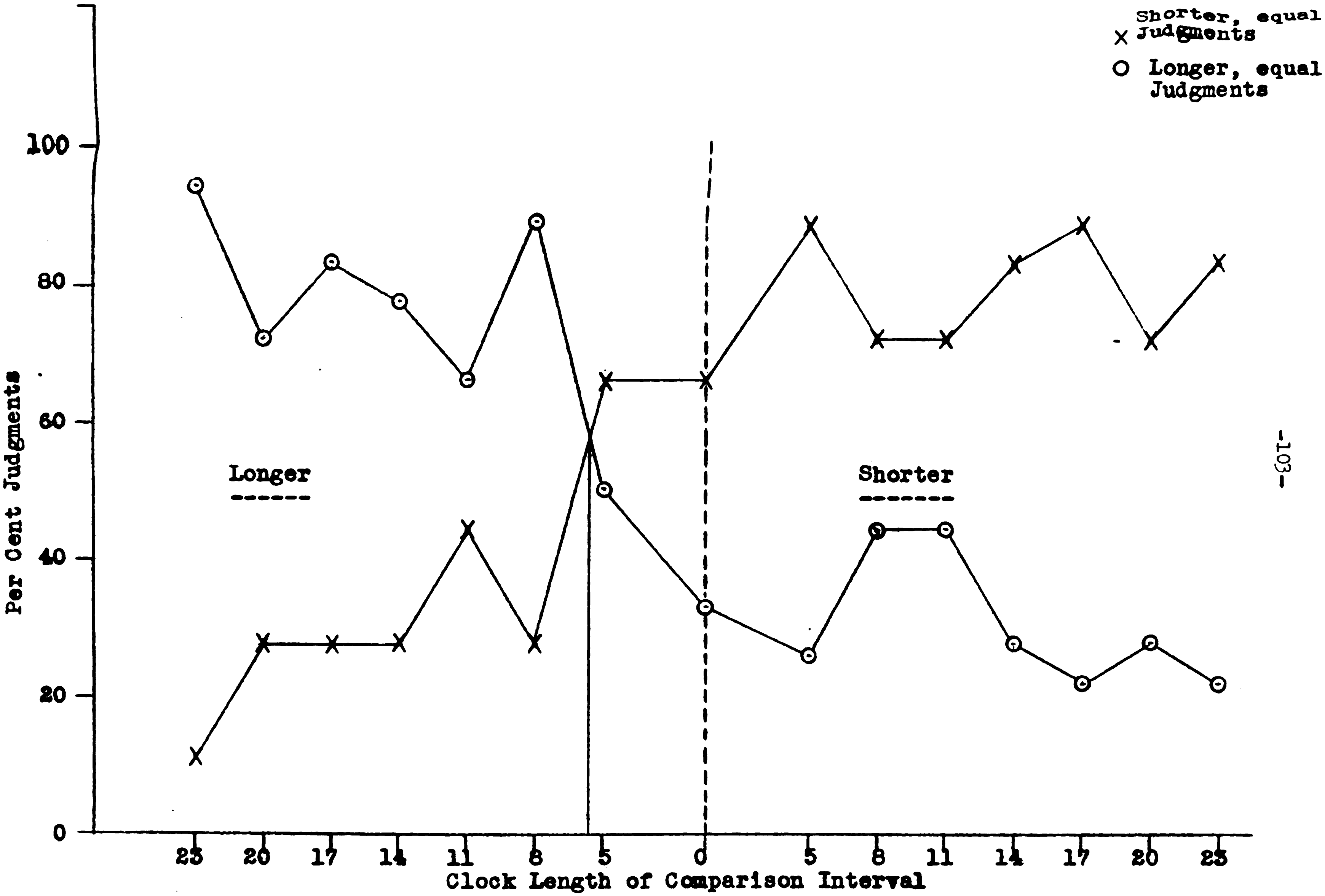

Figure 20. The experimental standard was set at a fixed phenomenal change rate for 90 seconds. The comparison was set at a fixed phenomenal change rate either 5 or 10 points below the rate of the standard on the phenomenal change scale and the clock length of the presentation was varied. 250 comparisons were made to fix the function.

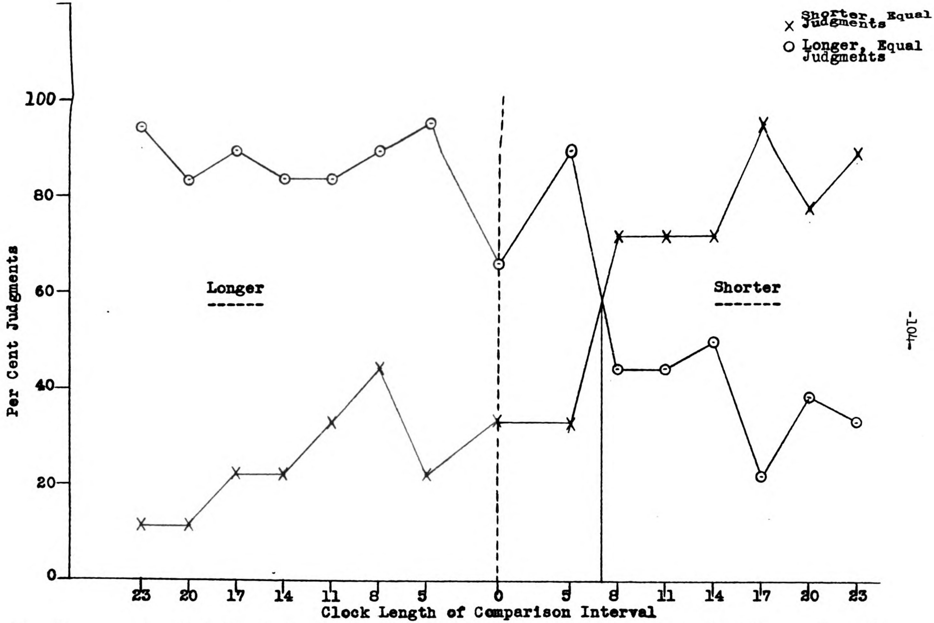

Figure 21. The experimental standard was set at a fixed phenomenal change rate for 90 seconds. The comparison was set at a fixed phenomenal change rate either 5 or 10 points above the rate of the standard on the phenomenal change scale and the clock length of the presentation was varied. 250 270 comparisons were made to fix the function.

Selecting an Experimental Interval of Phenomenal Movement

Experiment 9.

Purpose: Experiment 9 was undertaken for exactly the same reasons as experiment 3. Previous experimentation does us no better service here than it did there. An empirical answer specific to the phenomenal movement condition is needed. Thus, experiment 9 was designed to determine the clock interval of phenomenal movement most satisfactory for use as the phenomenal interval in later experimentation.

Subjects: Six subjects naive to the purposes of the experiment were used. All were college students in their twenties; 3 were male and 3 female.

Apparatus: The apparatus is identical to that previously described in experiment 2 with one exception. During experiment 9 the doorbell was eliminated and the Burgess sprayer motor was used alone as a masking sound.

Method: The method was identical to that employed in experiment 3 except that phenomenal movements were substituted for phenomenal changes. Table 1 can serve as a schematic representation of the experiment if the reader will substitute the word "movement" for "change" wherever the latter occurs.

<u>Procedure</u>: The procedure was identical to that employed in experiment 3 except that the word "movement" was substituted for "Kaleidoscopic change" in the directions.

<u>Results</u>: The results are resumeed in Figures 22 and 23. Figure 20 was prepared from the average responses at each time level used. The responses were averaged by assigning each equal response a weight of 200, each shorter response a weight of 100, and each longer response a weight of 300. Figure 21 contains plots of the separate judgments.

The plots of the data in Figures 22 and 23 do not show a single indifference point, although trends similar to those occurring in experiments 3 and 4 are present. That is, the tendency for the comparison interval to be experienced as being longer than the standard increases as the length of the pairs increases. Considering just Figure 23, it can be seen that there are three points of phenomenal equality occurring between the 25 and 45 second intervals. Figure 23 shows that with few exceptions the comparison interval is experienced as being longer than the standard, although somewhere between 60 and 135 seconds this tendency becomes very marked.

<u>Conclusions</u>: Although there were several points on the clock continuum where little bias occurred, no interval was found which can be called the "indifference point". Neither was there a point at which the time errors could be said to

have changed from positive to negative. The judgments, however, became increasingly skewed as the intervals lengthened. As the intervals became longer in clock time, they became more likely to be experienced as being longer than the standard. This is in agreement with the findings of the phenomenal change experiment 3. Systems of phenomenal movement, however, appeared to yield more variable comparisons of duration than did those of the analogous phenomenal change experiment.

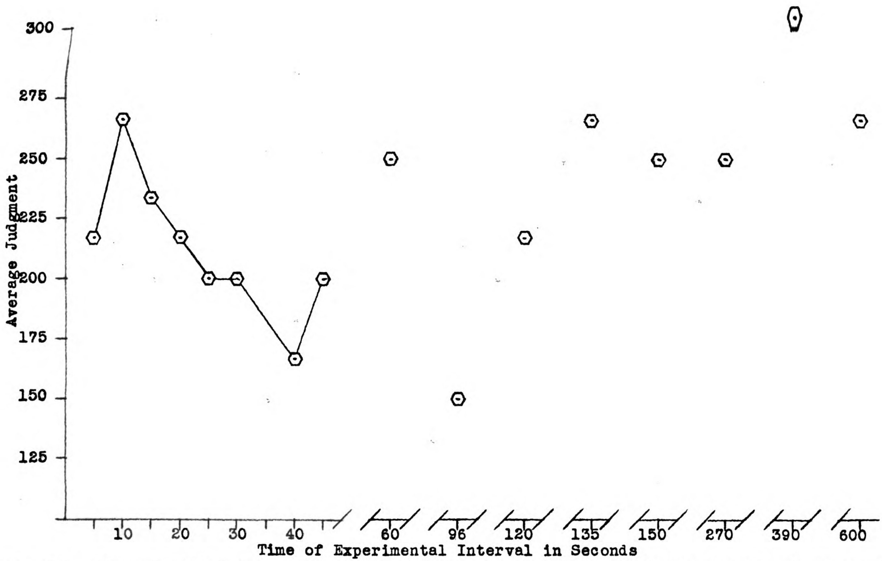

Figure 22. The relation between comparisons of the phenomenal durations of phenomenal movements and the clock lengths employed experimentally. Each point plotted represents the mean of 6 comparisons. The standard and comparison intervals were all equal in clock length and the phenomenal movement rate remained constant throughout each experimental presentation.

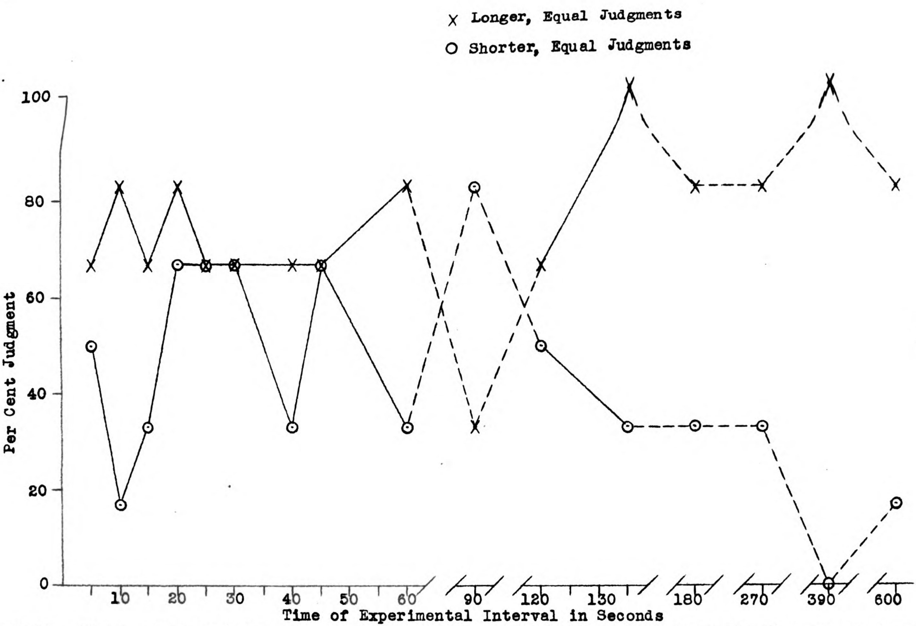

Figure 23. Three category judgments when phenomenal movements of various clock lengths were employed. 6 comparisons were made for each time length; standard and comparison intervals were equal in clock length. The phenomenal movement rate was constant for each experimental pair presented.

Experiment 10.

Purpose: Experiment 10 is an extension of experiment 9. It is a further attempt to select a clock length for use as the standard interval in later experimentation involving the experienced endurance of phenomenal movement.

Subjects: A total of 6 subjects were used. All subjects were college students; 4 were male and 2 female. All were naive regarding the aim of the experimentation.

Apparatus: The apparatus was identical to that described in experiment 9.

Method: The method employed was identical to that described in experiment 4, except that phenomenal movements were used in place of phenomenal changes. Table 2 can serve as a schematic representation providing the reader substitutes the word "movement" for "change" wherever the latter occurs.

Procedure: The procedure followed was identical to that employed in experiment 9.

Results: The comparisons made when the rate for the comparison interval was lowered are plotted in Figure 28. The comparisons for the raised rate are plotted in Figure 29. Figure 24 includes the total comparisons made for experiment 10, plus the comparisons of experiment 9 in which the appropriate intervals were used.

These three figures show that in general the frequency of longer comparisons increases while the shorter comparisons decrease as the clock length of the intervals increase. These figures also show that it is not possible to assign an indifference interval in the sense the term was originally used, although, one would suspect that the interval of minimal bias lies between the 30 and 180 second experimental intervals. One may obwerve in the composite graph (Figure 24) that at 30 seconds the equal judgments are at their peak and comparisons of longer and shorter occur with equal frequency. In contrast, at 180 seconds, the graph shows the errors changing from positive to negative.

Figures 28 and 29 also show that there is a greater preponderance of "short" comparisons when the phenomenal movement is changed from a high standard to a low comparison than when the opposite is true. This suggests that the rate of phenomenal movement may have some relationship to the experience of duration.

Conclusions: A single indifference point was not found. Neither did there seem to be a single place on the clock length continuum where the time errors changed from positive to negative. The point of minimal biasing apparently lies somewhere between 30 and 180 seconds. Consistent with the findings for phenomenal change in experiments 3 and 4, the liklihood of the comparison interval being experienced as longer increased as the experimental pairs increased in length. A specific interval for phenomenal duration experimentation should be selected from this range. The interval selected should be that showing minimum bias.

Experiments 11, 12 and 13.

Purposes: Data from experiments 8 and 10 indicate that minimal biasing of response will occur somewhere between 30 and 180 seconds, when the method of comparisons is used for durations of phenomenal movement. Intervals lying between these limits would all be sufficiently long for our purposes. Bearing this finding in mind, experiments 11, 12 and 13 were designed to select a definite experimental interval for a system of phenomenal movements for use in the study of phenomenal duration. Specifically, the purpose of these three experiments is to determine which of three possible experimental intervals, 30, 90 or 180 seconds, will yield the greatest reliability of comparison.

Subjects: In experiment 11, a total of 13 subjects were used; 3 were female and 10 male. In experiment 12, 13 subjects were used; 4 were female and 9 male. In experiment 13, 6 male subjects were used. All subjects were college students and all were naive regarding the purpose of the experiments.

Apparatus: The apparatus is identical to that described for experiment 9.

Method: The methods employed for experiments 11, 12 and 13 were identical to those described for experiments 5, 6 and 7 respectively, except that phenomenal movements were substituted for phenomenal changes. Tables 3, 4, and 5 may be used as schematic representations of the method used in experiments 11, 12, and 13 respectively, provided the word "movement" is substituted for "change" wherever the latter occurs.

Procedure: The procedure was identical to that followed in experiment 9.

Results: Figure 25 summarizes the results of experiment 11. This graph shows a clear point of phenomenal equality at the 30 second interval. The relative absence of reversals in the functions indicates an acceptable reliability of comparison.

Figure 26 resumes the results of experiment 12. The functions plotted in this graph show a clear-cut point of phenomenal equality also. The biasing and variability of comparison is somewhat greater than was the case with the 30 second interval.

Figure 27 presents the results of experiment 13. This graph presents a complicated picture. Although several of the subjects used in experiments 11 and 12 served in experiment 13, multiple points of phenomenal equality occurred and there was great variability of comparison.

Conclusions: Using extent of biasing and reliability of comparison as criteria, the results of experiments 11, 12 and 13 indicate that either a 30 second or 90 second phenomenal movement interval will be satisfactory for use in a phenomenal duration study. The differences between the 30 and 90 second intervals favor the former slightly. It seems best to select the 90 second in preference to the 30 second interval for use, however. The reasons for this are: a) the differences between the 30 and 90 second intervals are not of much magnitude; b) a phenomenal change interval of 90 seconds must be used for the duration experiment; and c) a 90 second phenomenal movement interval will allow greater possibility of variations in the design of later experiments. A 180 second interval would be unsatisfactory for experimental use due to instabilities in the comparisons.

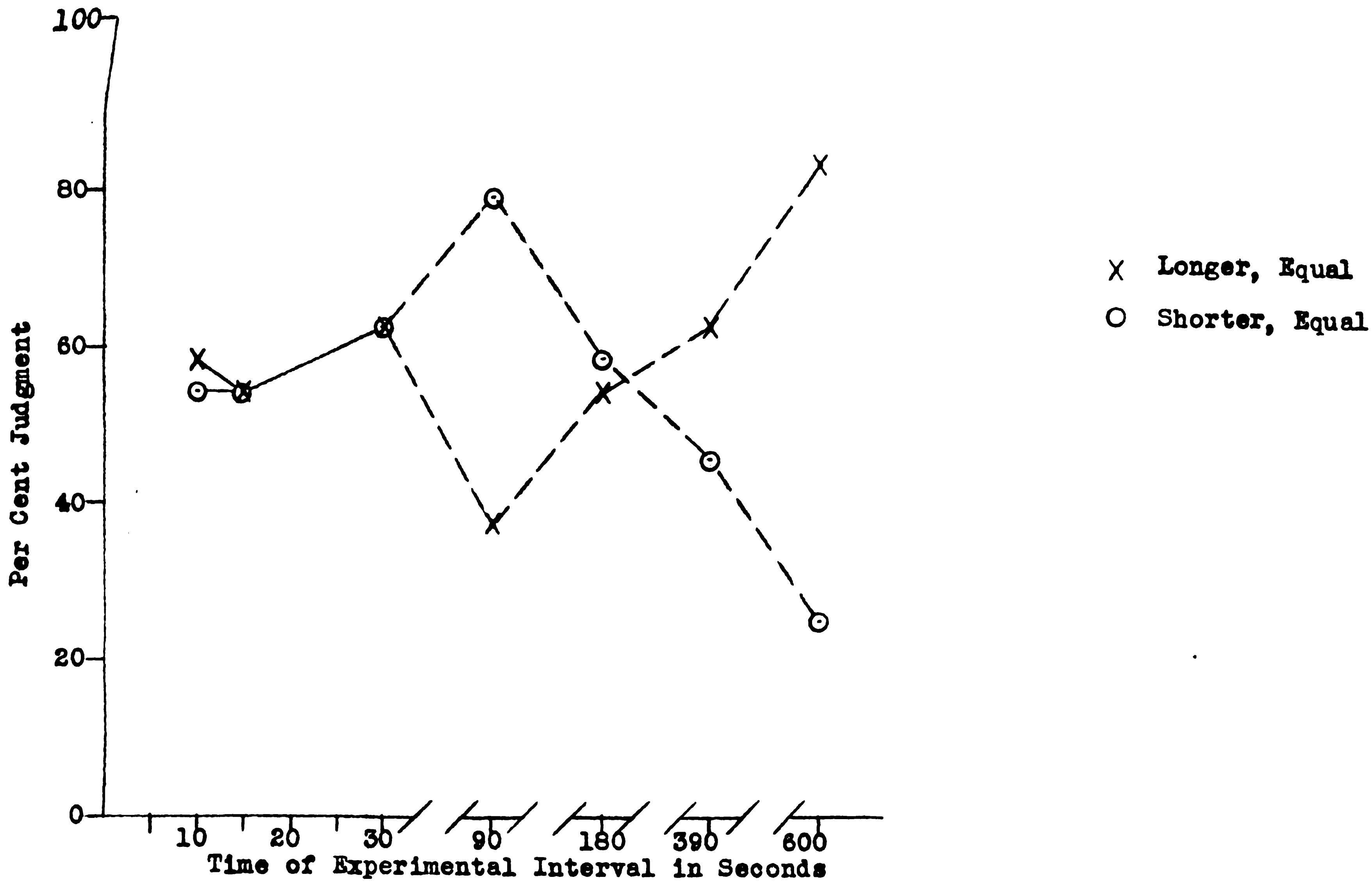

Figure 24. Three category judgments when phenomenal movements of various clock lengths were employed. 24 comparisons were made for each time length; standard and comparison intervals were equal in clock length. The phenomenal movement rate was constant from standard to comparison interval for 6 of the 24 comparisons, decreased for 9, and increased for 9.

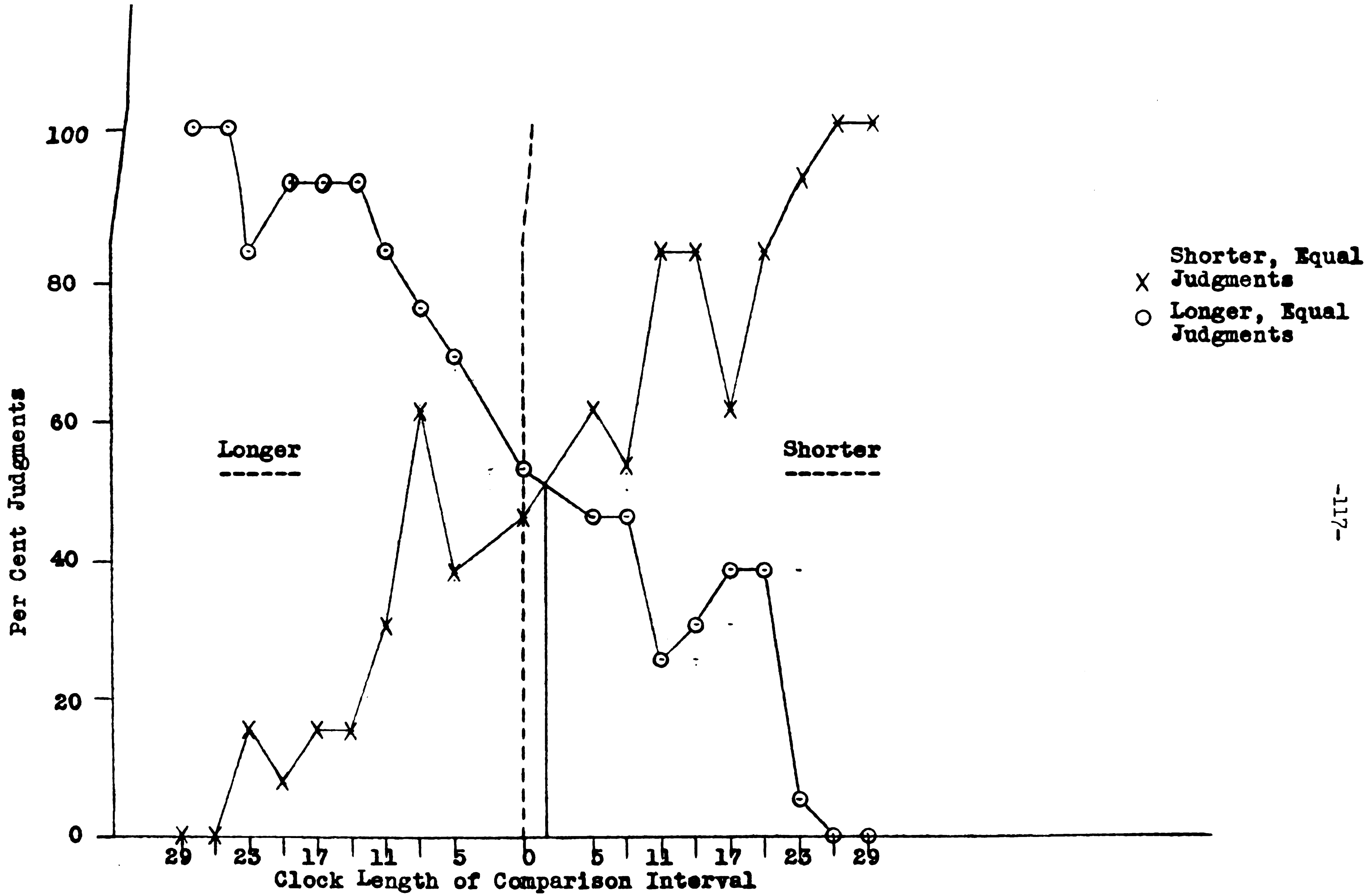

Figure 25. The standard phenomenal movement interval was set at 30 and the comparison phenomenal movement interval varied in clock length. The phenomenal movement rate was held constant experimentally during both the standard and comparison intervals. 250 comparisons were made to fix the function.

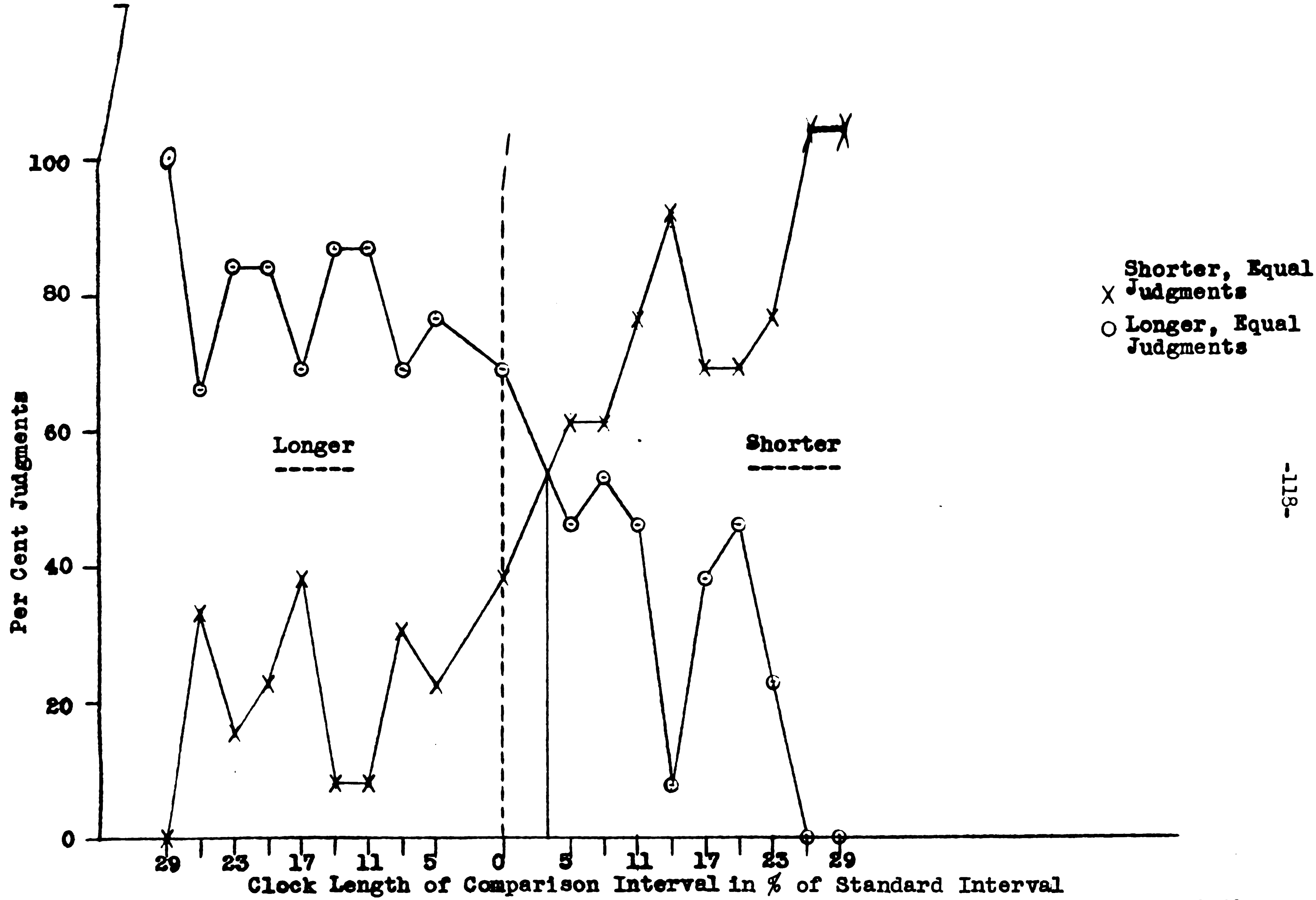

Figure 26. The standard interval was set at 90 seconds for the phenomenal movement interval and the comparison interval varied in clock length. The phenomenal movement rate was held constant during the standard and comparison intervals. 250 comparisons were made to fix the function.

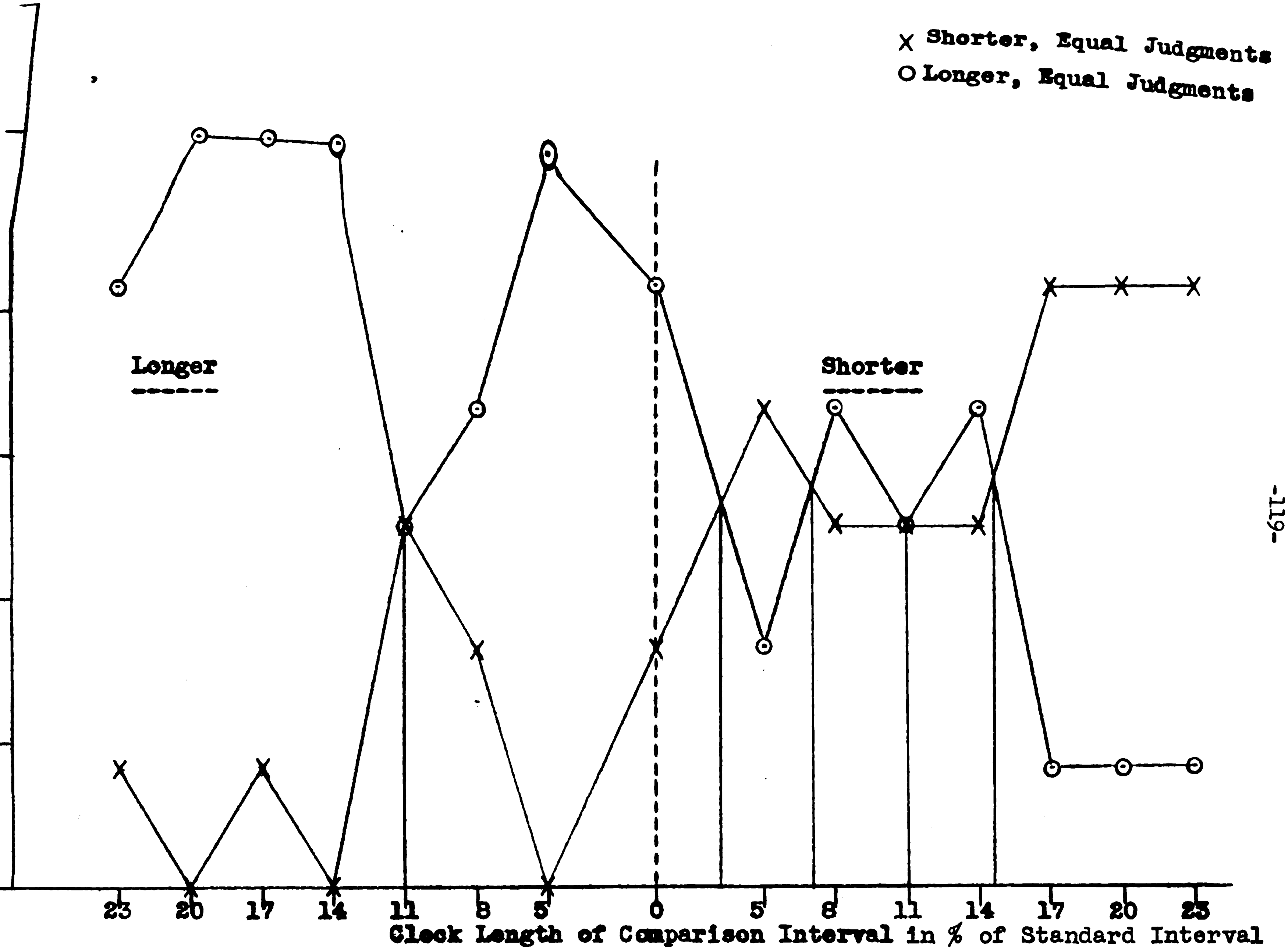

Figure 27. The standard interval was set at 120 seconds for the phenomenal movement interval and the comparison interval varied in clock length. The phenomenal movement rate was held constant experimentally during both the standard and comparison intervals. 96 comparisons were made to fix the function.

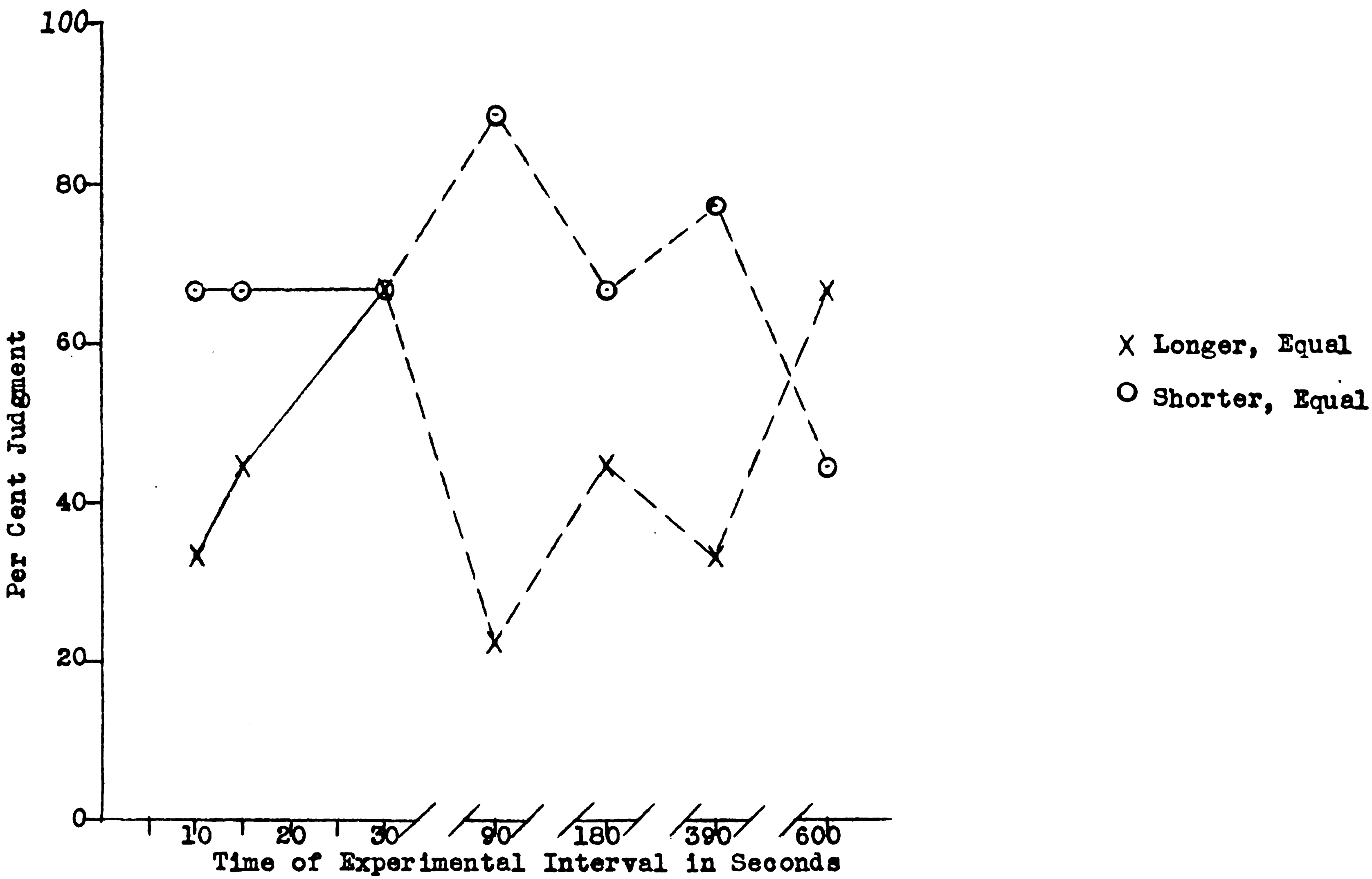

Figure 28. Three category judgments when phenomenal movements of various clock lengths were employed. 9 comparisons were made for each clock length; standard and comparison intervals were equal in clock length. The rate during the comparison interval was a steady 5 or 10 points below the standard phenomenal movement scale rate.

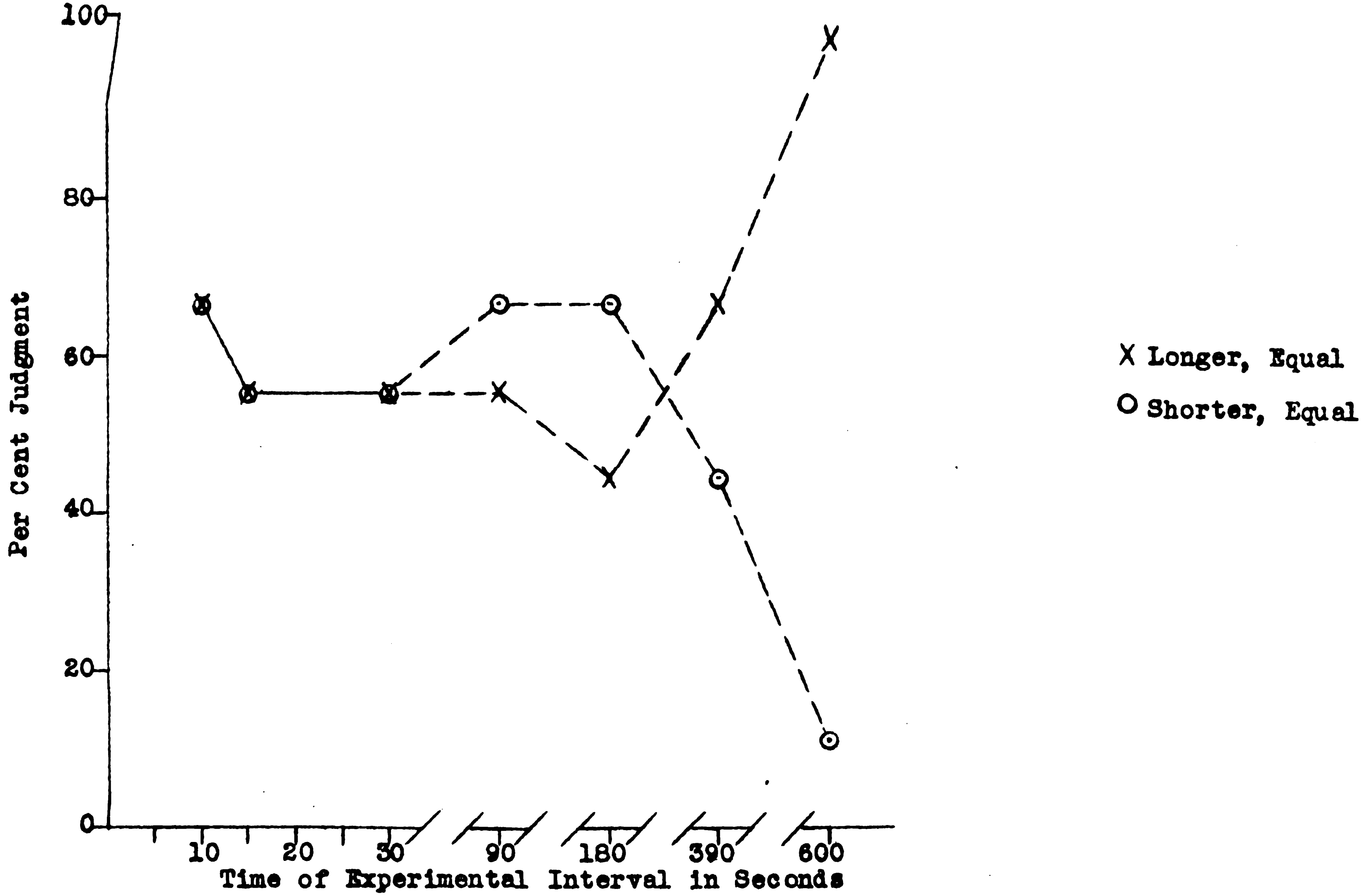

Figure 29. Three category judgments when phenomenal movements of various clock lengths were employed. 9 comparisons were made to fix each clock length; standard and comparison intervals were equal in clock length. The rate during the comparison interval was a steady 5 or 10 points above the standard phenomenal movement scale rate.

The Experienced Duration of Various Systems of Phenomenal Movement Maintaining a Constant Pace

Experiment 14 A.

Purpose: Experiment 10 directly suggests that the experience of duration differs according to whether the duration is a slow or rapid phenomenal movement. Specifically, the distribution of data in Figures 28 and 29 shows that when the standard interval features a rapid phenomenal movement (See Figure 10 for the phenomenal movement scale) and the comparison interval a slower phenomenal movement, that there is a much greater likelihood of the comparison being experienced as being shorter than the standard than when the opposite order occurs. Experiment 14A constitutes an investigation into the relationship of phenomenal movement to the experience of duration.

Subjects: There were 10 subjects used in total; 2 were female and 8 were male. All were college students and naive to the purposes of experimentation.

Apparatus: The apparatus is identical to that described in experiment 9.

Method: The method of comparison was used, and the standard interval always occurred first. The clock length of the standard was always 90 seconds. Three category judgments were allowed. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between pairs.

The standard and comparison intervals of each pair differed as regards the rate of phenomenal movement and as regards clock length. With respect to phenomenal movement, the following variations were made. A total of 270 comparisons were made when the comparison exceeded the standard in phenomenal movement rate. Specifically, 90 presentations were made with the standard at phenomenal movement (See Figure 10) and the comparison at phenomenal movement 12, 90 presentations with the standard at 2 and the comparison at 7, 90 presentations with the standard at 7 and the comparison at 12. Another 270 comparisons were made when the opposite was the case, when the standard exceeded the comparison in change rate. Specifically, 90 presentations were made with the standard at phenomenal movement 12 and the comparison at phenomenal movement 2, 90 presentations with the standard at 12 and the comparison at 2. With respect to clock length, the following differences were present. The clock length of the comparison interval was 0, 5, 8, 11, 14, 17, 20 or 23% longer or shorter than the standard interval.

All 540 pairs were presented according to a random plan. Table 6 can be used as a schematic representation of

the experimental method, providing the word "movement" is substituted for "change" wherever the latter occurs.

Procedure: The procedure was identical to that employed in experiment 9.

Results: Figure 30a represents the responses made when the comparison interval was set at a phenomenal movement rate less than the standard rate. Figure 31a represents the responses made when the comparison interval was set at a phenomenal movement rate greater than the standard.

The figures do not show a clear-cut difference in the preponderance of either "longer" or "shorter" responses. The "longer" and "shorter" functions of both figures show reversals of direction. The variability of comparison in both cases does not permit the assignment of a definite point of phenomenal equality. However, it is clear that the zone of phenomenal equality lies more toward the "short" end when the comparison movement is rapid than when it is slow.

Conclusions: The systems of phenomenal movement used in experiment 14A proved difficult for the subjects to compare as regards duration. No clear-cut point of phenomenal equality was found and the functions themselves show reversals of direction. The comparisons made were relatively unreliable. The differences that do exist indicate that a rapid rate of phenomenal movement must have a somewhat longer clock length than a slow rate if the intervals are to result in an equal phenomenal duration.

The results of experiment 14 can thus be contrasted with the findings of experiment 10. Experiment 10 shows that the general skewing of comparisons is in the direction of "shorter" while experiment 14A shows an opposite relationship. Moreover, there is poor agreement respecting the specific effects of rapid and slow systems of phenomenal movement.

The results of experiment 14A are also in contrast to the results of experiment 8, which in all respects is an analogous phenomenal change experiment. In experiment 8, the comparison of "longer" was in the greatest preponderance and rapid rates of phenomenal movement needed a considerably shorter clock length than slow rates if the intervals were to result in an equal phenomenal duration.

The findings lend validity to the distinction between phenomenal change and movement.

Experiment 14B.

The results of experiment 14A were not as clear-cut as might be desired. The production of a zone of phenomenal equality rather than a point and the occurrence of reversals in the functions were unexpected. Hence it is desirable to increase the number of observations and to increase the difference in rates of movements distinguishing the standards from comparison intervals.

Subjects: A total of 28 subjects were used; 9 were female and 19 male. All were college students and all naive to the purposes of experimentation.

Apparatus: The apparatus is identical to that described in experiment 9.

Method: The method of comparison was employed and the standard interval always occurred first. The clock length of the standard was always 90 seconds. Three category judgments were allowed. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between pairs.

The standard and comparison intervals of each pair differed as regards the rate of phenomenal movement (See Figure 10) and as regards clock length. With respect to phenomenal movement, the following variations were made. A total of 180 comparisons were made with the standard at phenomenal movement

2 and the comparison at phenomenal movement 12, and another 180 comparisons were made with the standard at phenomenal movement 12 and the comparison at phenomenal movement 2. With respect to differences in clock length, the comparison interval was either 0, 5, 8, 11, 14, 17, 20 or 23% longer or shorter than the standard interval.

All 260 pairs were presented according to a random plan. Table 6 can be used as a schematic representation of the experimental method provided the columns under "standard 7" are omitted and providing the word "movement" is substituted for "change" wherever the latter occurs.

<u>Procedure</u>: The procedure was identical to that employed in experiment 9.

<u>Results</u>: Figure 30b represents the responses made when the comparison interval was set at a phenomenal rate less than the standard rate. Figure 31b represents the responses made when the comparison interval was set at a phenomenal movement rate greater than the standard.

The figures do not show a clear-cut preponderance of either "longer" or "shorter" responses. The longer and shorter functions of both figures show reversal of direction. The variability of comparison in both cases does not permit the assignment of a definite point for phenomenal equality. It seems evident, however, that the phenomenal equality lies more toward the "long" end when the comparison movement is rapid than when it is slow.

Figure 32 represents the total responses made in experiments 14A and 14B when the comparison interval was set at a phenomenal movement rate less than the standard. Figure 33 represents the total responses made in experiments 14A and 14B when the comparison interval was set at a phenomenal movement rate greater than the standard. Each figure represents 450 comparisons, but since the biasing occurred in different directions from experiment 14A to 14B the plots do not show clear-cut points of phenomenal equality.

Two subjects reported that they were unable to use either interval as the comparison interval but could only report which of the two presented was longer or which was shorter.

Conclusions: The results of experiment 14B show, as does experiment 14A, that phenomenal movement is difficult for the subjects to characterize as a phenomenal duration. No clear-cut point of phenomenal equality was found and the functions show reversals in direction. These facts again suggest that the comparisons made were unreliable. Unreliability is further suggested by the fact that rapid rates of phenomenal movement needed longer clock length than the slow rates to achieve phenomenal equality, where in experiment 14A the opposite was true. In this latter respect, however, the results of experiment 14B are in good agreement with the results of experiment 10.

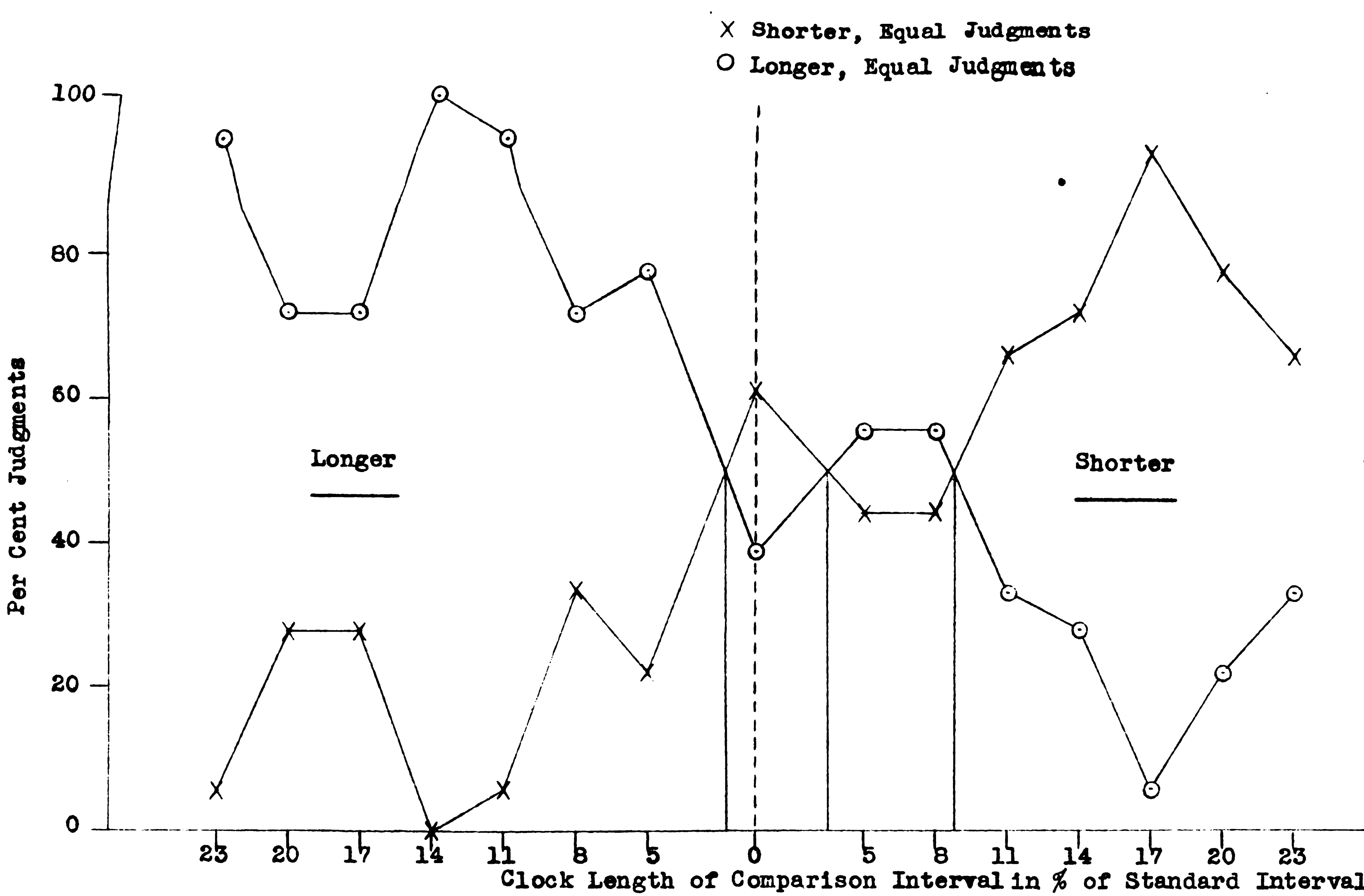

Figure 30-A. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points below the rate of the standard ...n the phenomenal movement scale and the clock length of the presentation was varied. 270 comparisons ...e made to fix the function.

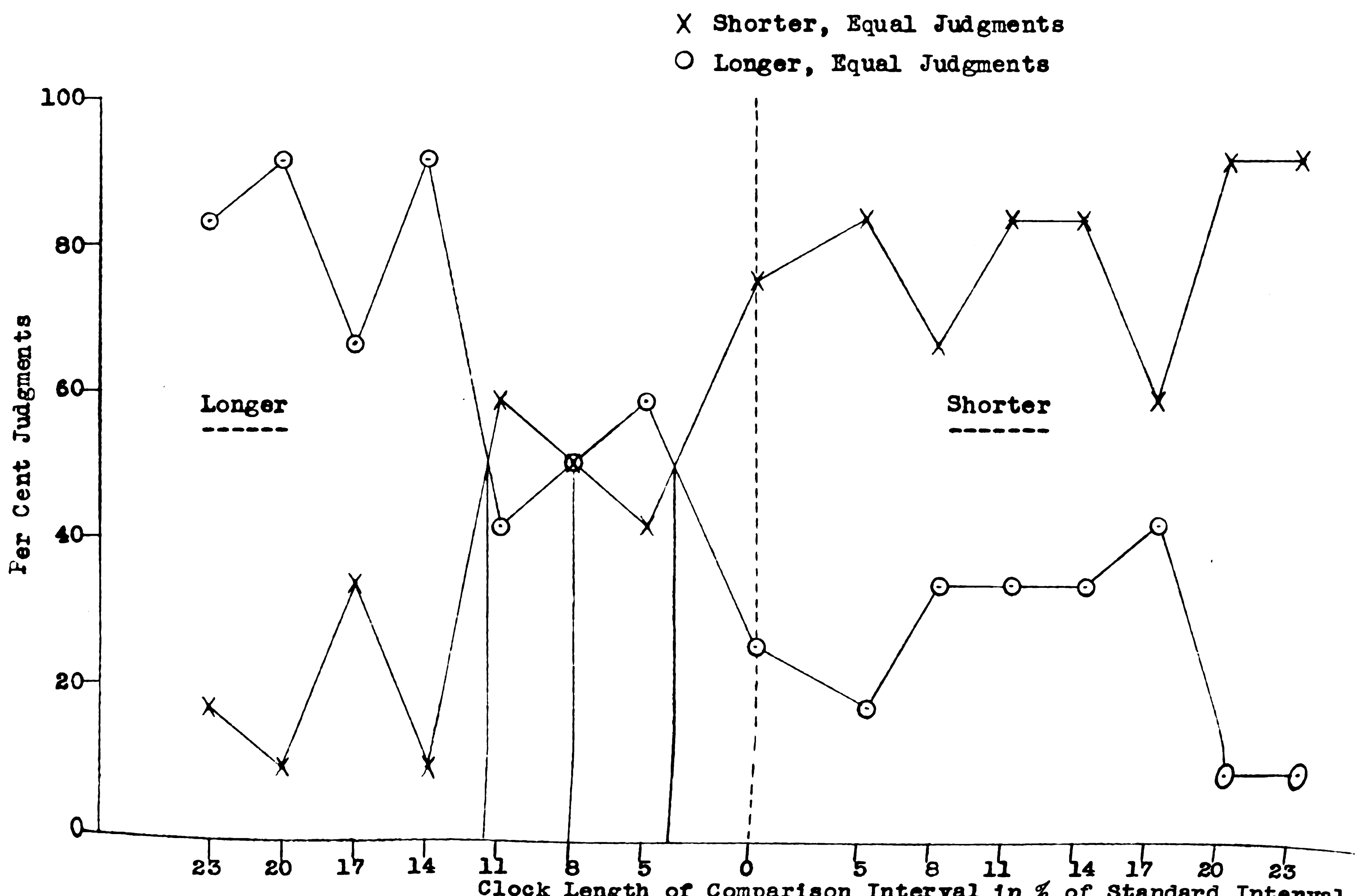

Figure 30-B. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 10 points below the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 192 comparisons were made to fix the function.

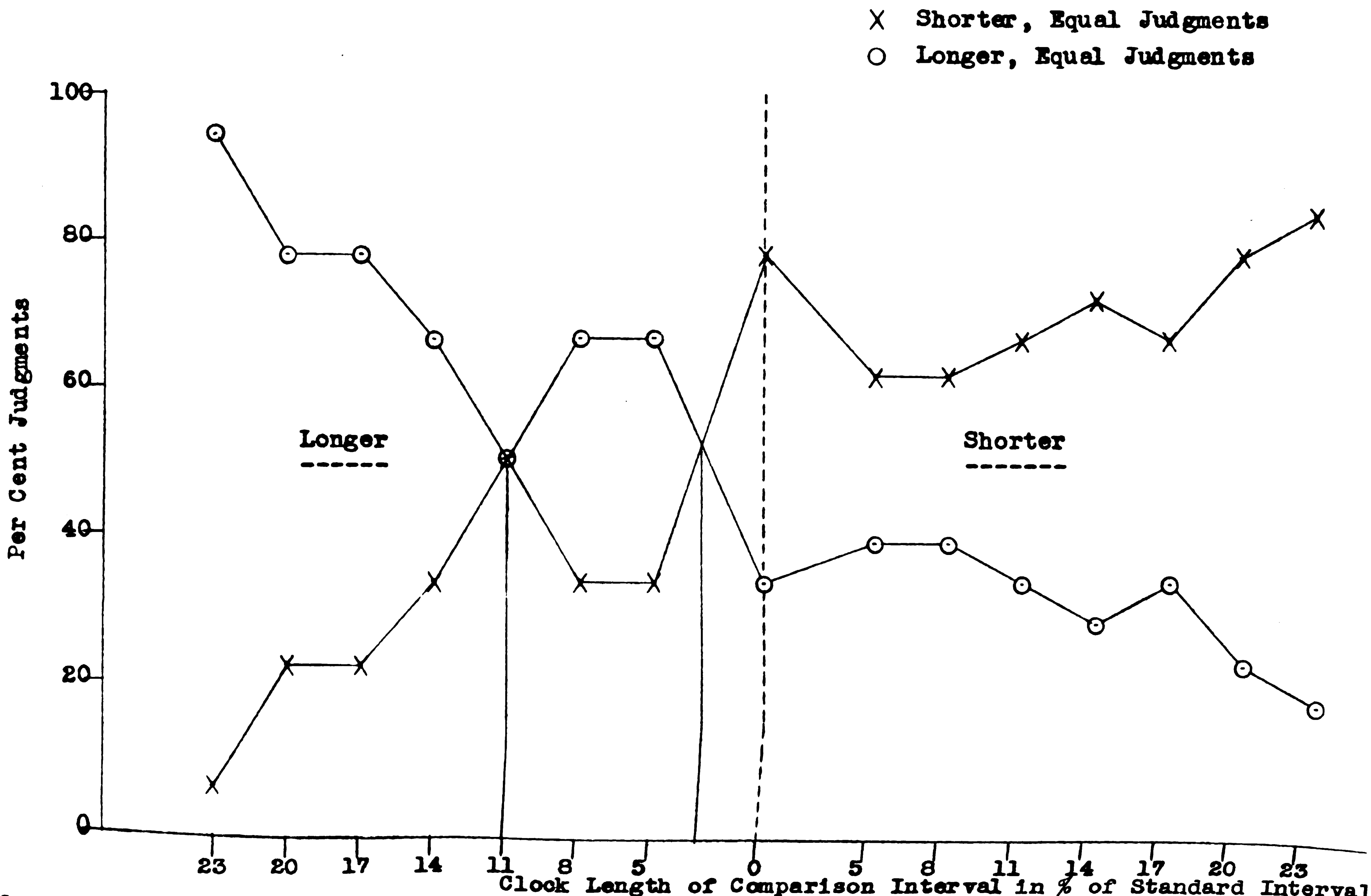

Figure 31-A. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points above the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 270 comparisons were made to fix the function.

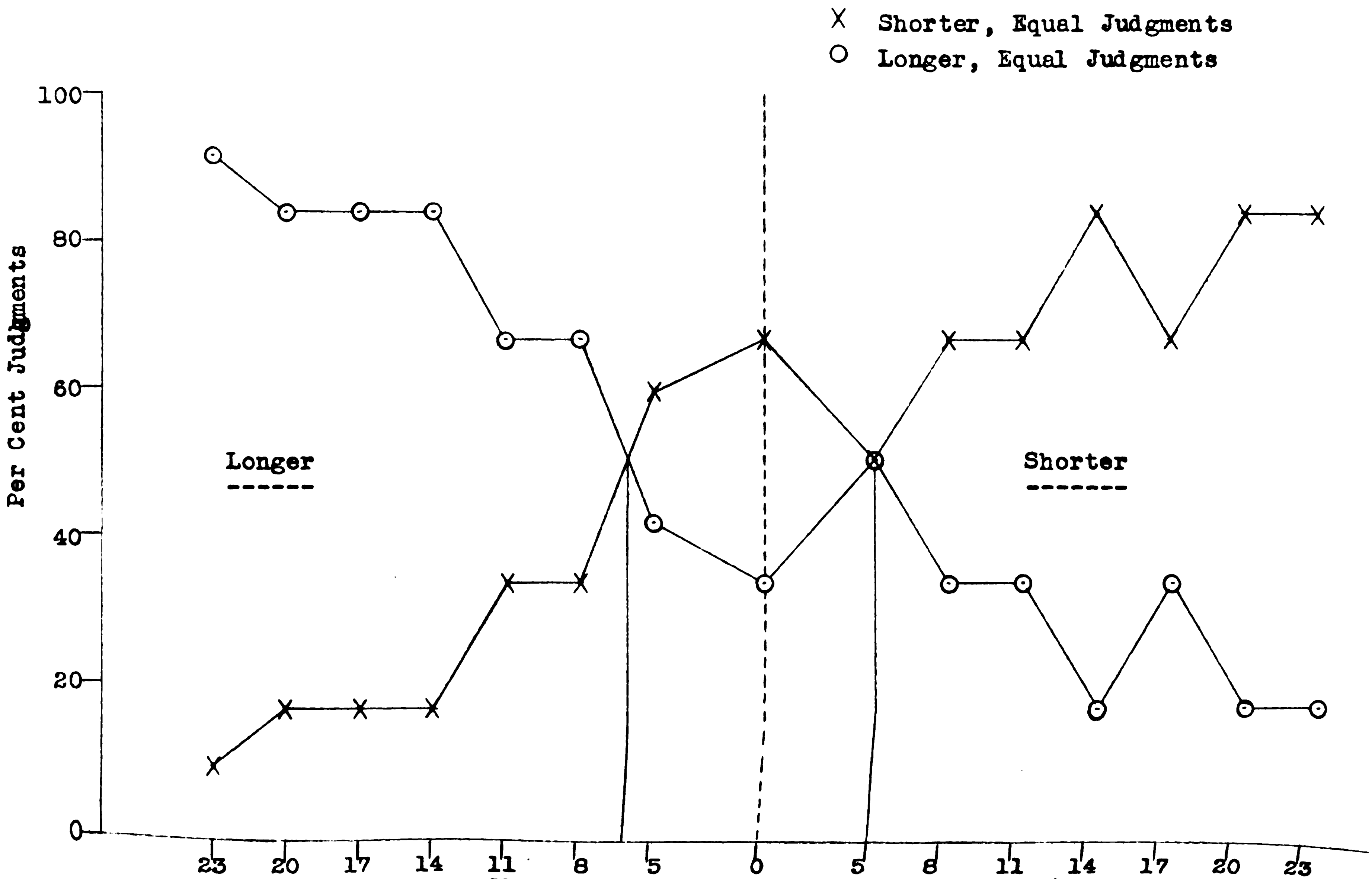

Figure 31-B. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 10 points above the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 192 comparisons were made to fix the function.

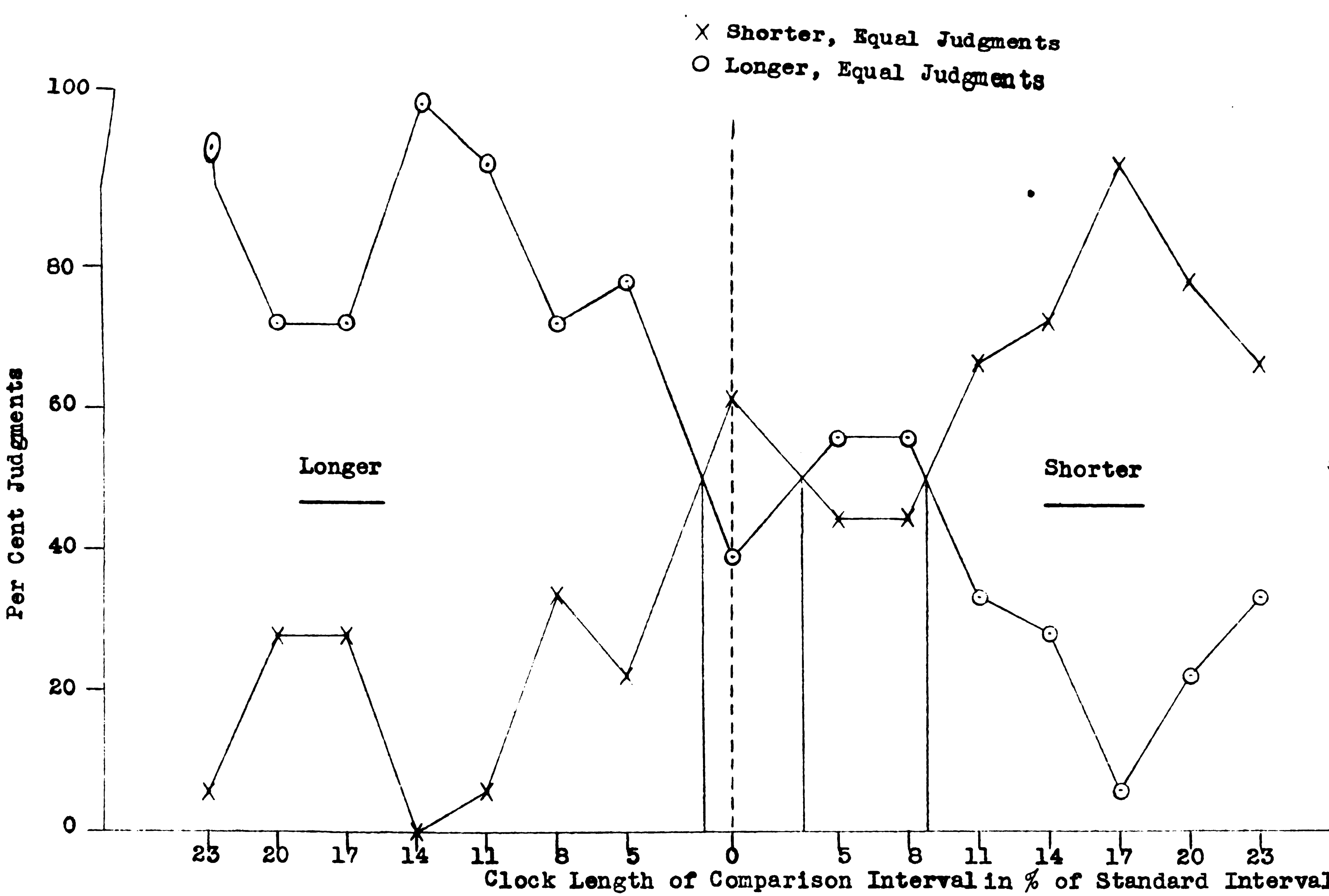

Figure 30-A. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points below the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 270 comparisons were made to fix the function.

Figure 50-B. The experimental standard, with

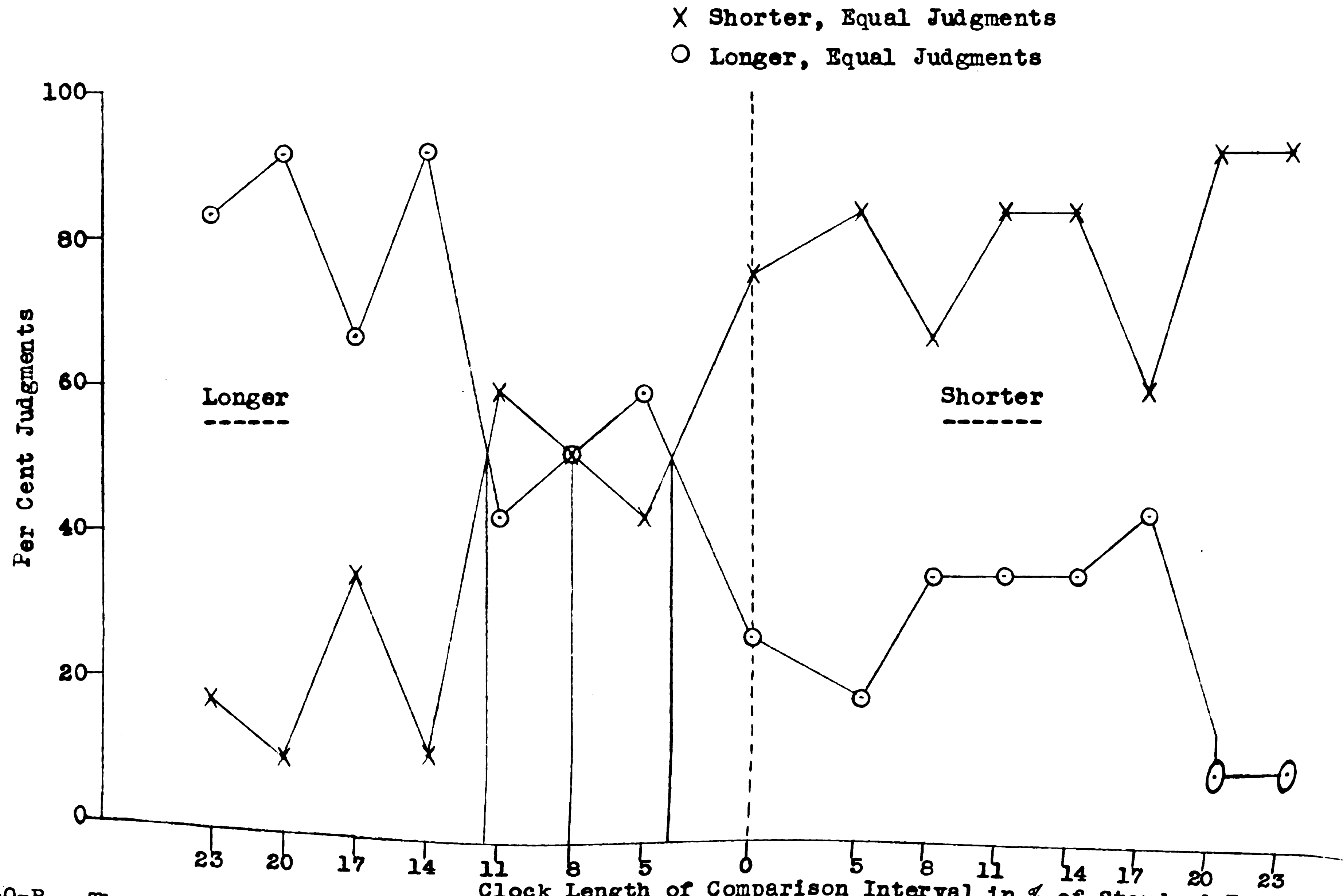

Figure 30-B. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 10 points below the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 192 comparisons were made to fix the function.

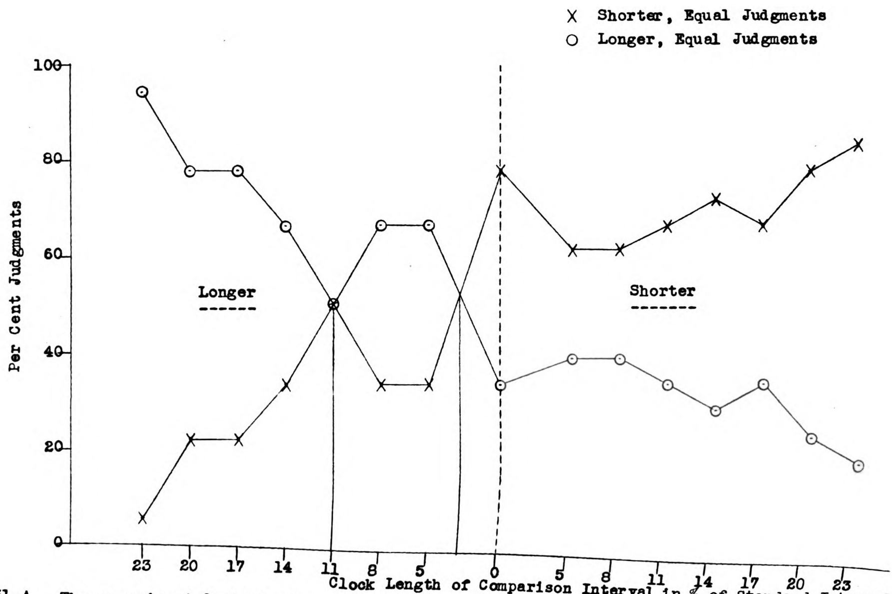

Figure 31-A. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points above the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 270 comparisons were made to fix the function.

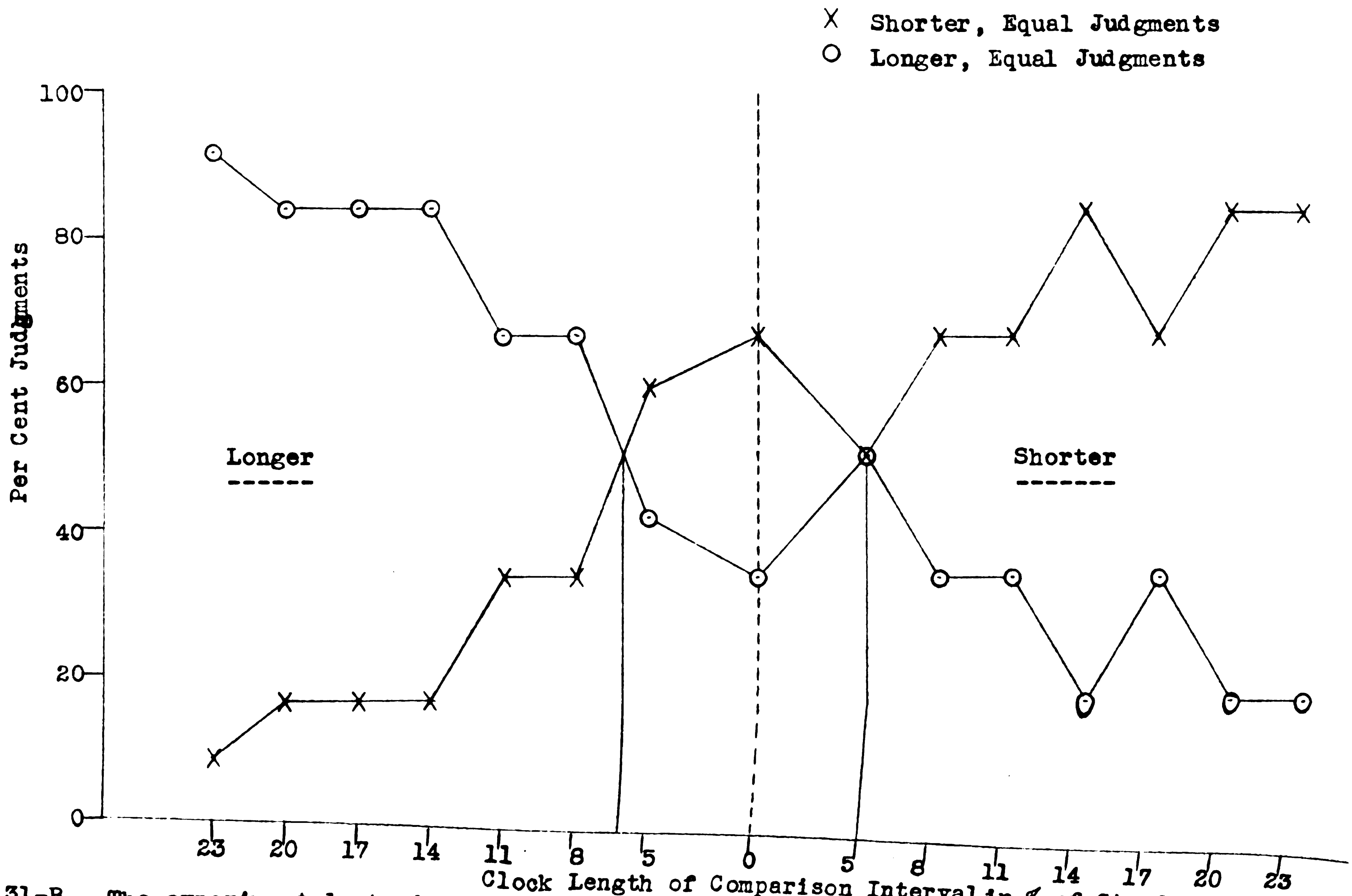

Figure 31-B. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 10 points above the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 192 comparisons were made to fix the function.

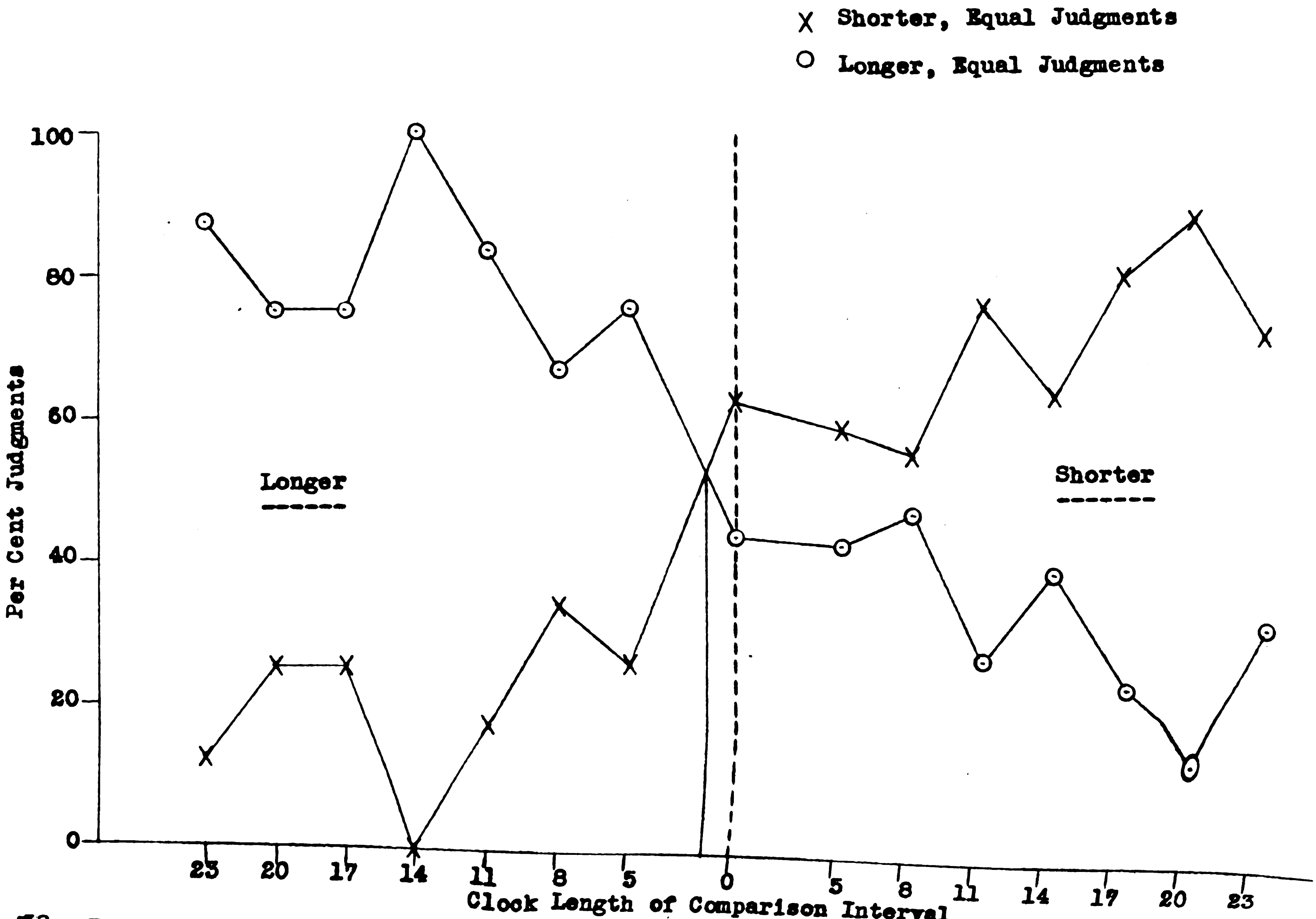

Figure 32. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points below the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 450 comparisons were made to fix the function.

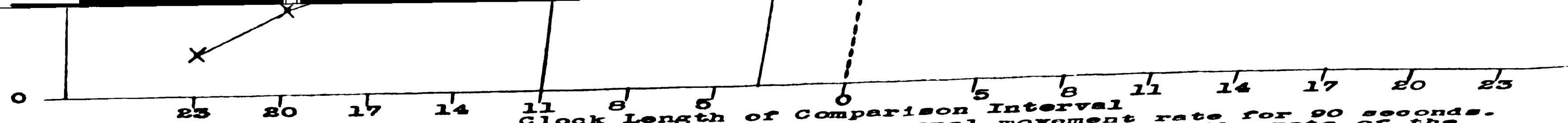

Figure 23. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points above the rate of the standard on the phenomenal movement scale, and the clock length of the presentation was varied. [illegible]

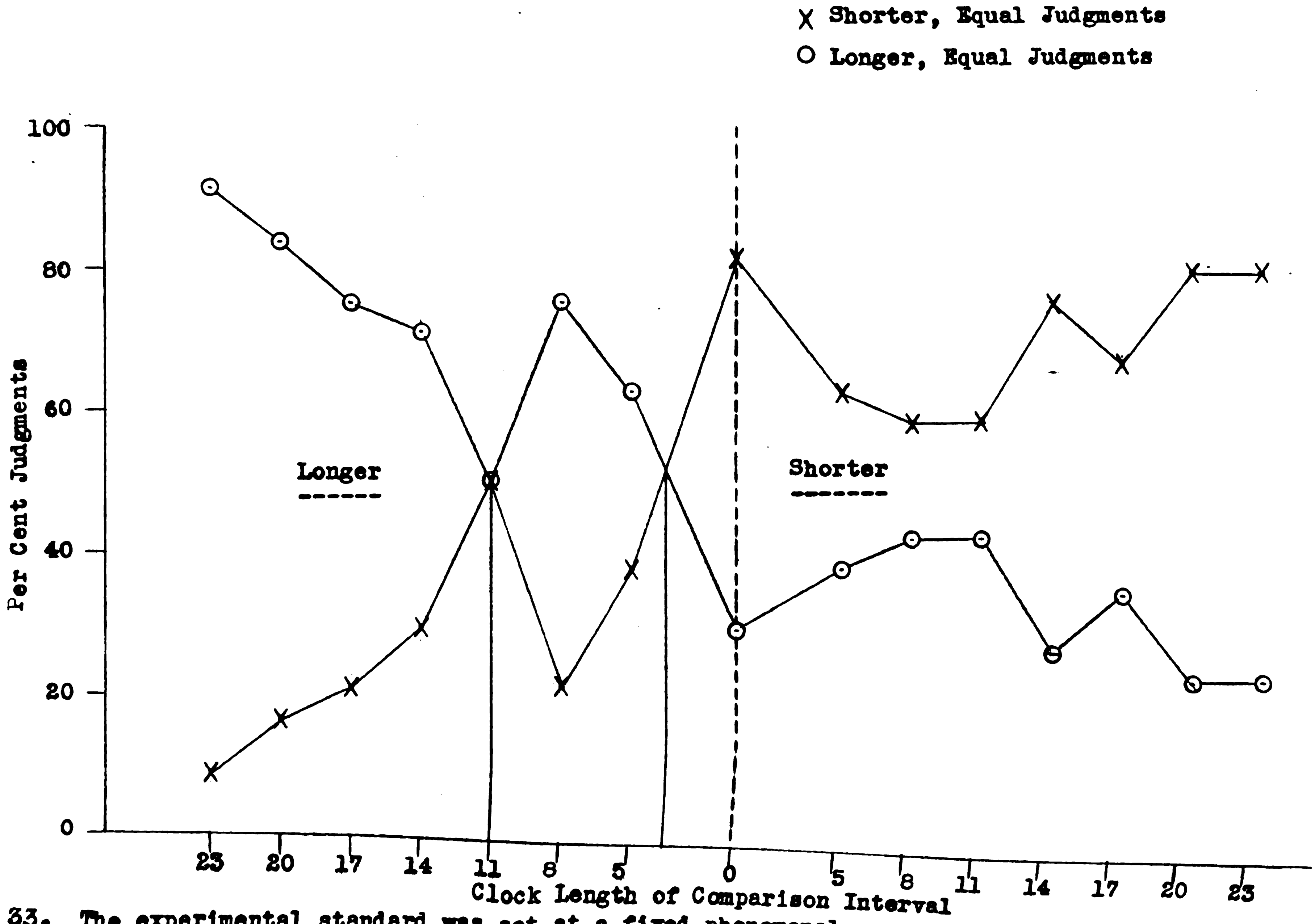

Figure 33. The experimental standard was set at a fixed phenomenal movement rate for 90 seconds. The comparison was set at a fixed phenomenal movement rate 5 or 10 points above the rate of the standard on the phenomenal movement scale and the clock length of the presentation was varied. 450 comparisons were made to fix the function.

The Experienced Duration of Various Accelerating or Decelerating of Movements.

Experiment 15.

Purpose: In experiment 14 it was concluded that a system of slow phenomenal movement will be experienced as having slightly less duration than a brisk system of movement of the same clock length. In this respect the outcome of experiment 14 is consistent with the findings of Brown[6] and later of Cohen, Hansel and Sylvester[7]. The complexity of the functions and the occurrence of several points of phenomenal equality found in the psychophysical functions of experiment 14 are not in harmony with prior experimental findings, however. The prior findings gave evidence that a rigid interdependency between phenomenal movement and phenomenal duration exists. This discrepency and the nature of the hypothesis, i.e. that phenomenal duration will vary as a function of phenomenal time, both demand that a further investigation be made.

The experimental equipment and method employed here does not limit us to simple serial movements and brief durations. The possibility of extending the investigations to more complex systems and to longer phenomenal endurances is open. Accordingly, the present experiment will investigate the duration associated with systems of movement which are either continually on the increase or continually on the decrease.

6. J.F. Brown, "On Time Perception in Visual Movement Fields," op. cit., pp. 233-248.
7. J. Cohen, C.E.M. Hansel, and J.D. Sylvester, "Interdependence of Space, Time, and Movement," Acta Psychol., XI(1955), pp. 361-372

Subjects: A total of 6 subjects were used, 5 male and 1 female. All subjects were college students and all were naive to the purpose of experimentation.

Apparatus: The apparatus was identical to that described in experiment 9.

Method: The method of comparisons was used and the standard interval always occurred first. The experimenter attempted to allow 7 seconds between the standard and experimental intervals and 15 seconds between experimental pairs. Three category comparisons were allowed.

The standard interval was a constant stimulus, always of 90 seconds in length and always set at a rate of 12 on the phenomenal movement scale. The comparison interval differed from the standard in two ways. First, the comparison interval, with respect to phenomenal movement, underwent a constant increase or decrease of rate throughout the whole comparison period. The method employed was the following: the phenomenal movement was begun at an arbitrary point and then according to the dictates of a randomized program of presentation was increased or decreased continuously at 2/3 miles per second throughout the whole comparison interval. Secondly, the comparison interval with respect to clock length was either 0, 5, 8, 11, 14, 17, 20 or 23% longer or shorter than the standard interval.

A total of 180 observations were made. Of this total, 95 comparisons were made with the movement constantly increasing and 95 comparisons were made with the movement constantly decreasing.

Table 8 is a schematic representation of the method used.

Procedure: The procedure was the same as that outlined in experiment 9.

Results: The results are summarized in Figures 34, 35 and 36. Figure 34 presents the total data for experiment 15. Figure 35 presents the data for the constantly descending phenomenal movements. Figure 36 presents the data for the constantly increasing phenomenal movement.

All three graphs show multiple points of phenomenal equality, and in each case the graphs contain plots of markedly periodic form. In this latter respect, the reversal of the functions at the extremes of the distribution are particularly impressive.

Conclusions: The experimental data again failed to show a close relationship between phenomenal duration and phenomenal movement. The zone of phenomenal equality and the magnitude of the inflections in the curves exceed those found in experiment 14 (Figures 30, 31, 32 and 33). At this juncture we must question whether hypothesis 2 does justice to the facts and whether prior investigators adequately abstracted the pertinent variables from their experimental situations. A possible reinterpretation will be discussed in the "General Conclusions" chapter. At this point it seems fair to say, on the basis of experiments 11, 12, 14, 15 and the antecedent work of Brown and Cohen, Hansel and Sylvester, that as the complexity of movement increases the human is less and less able to assign a specific duration to it.

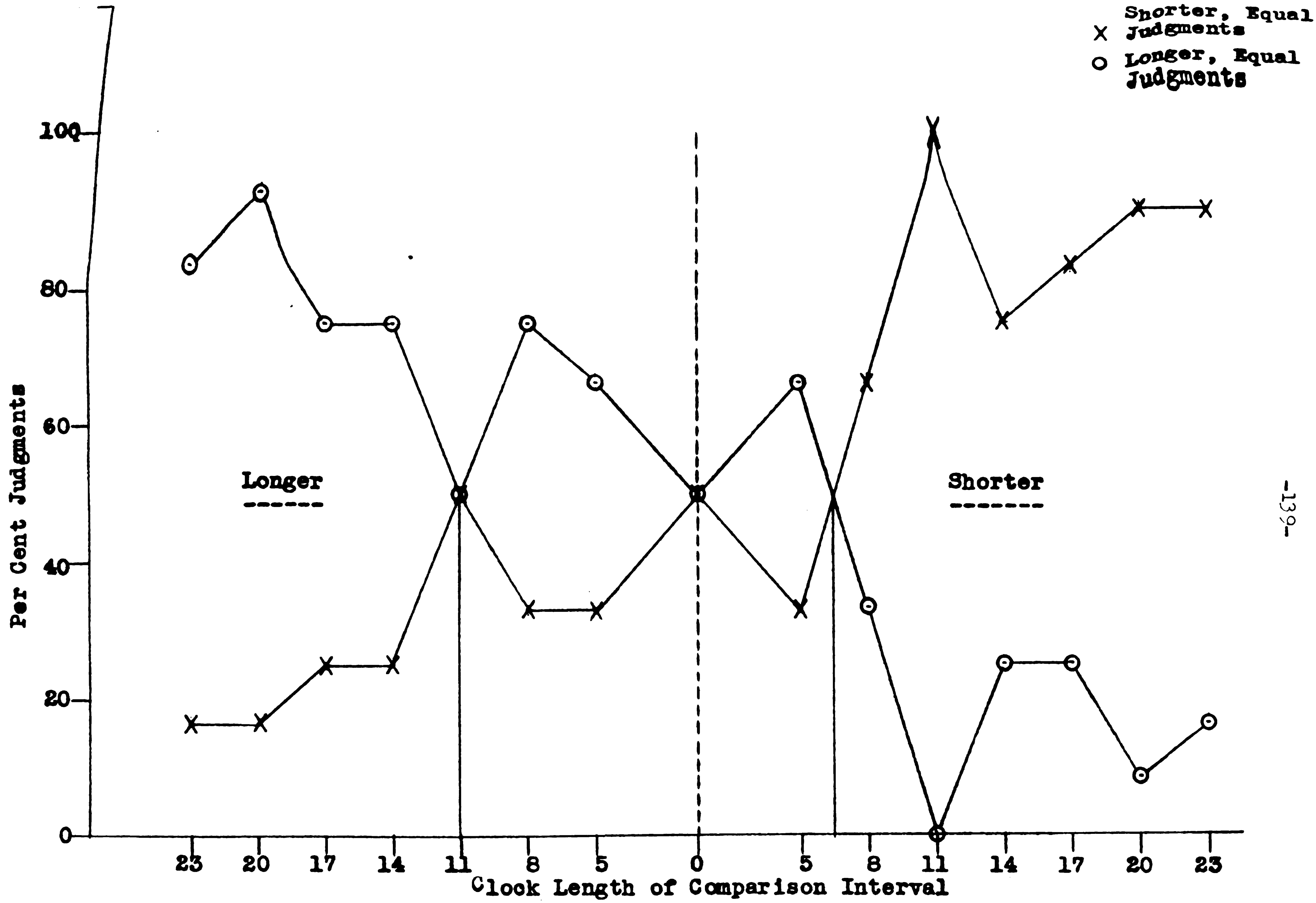

Figure 34. The phenomenal movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval the whole system of phenomenal movements was continuously accelerated or decelerated at a rate of 2/3 miles per second. 180 comparisons were made to fix the function.

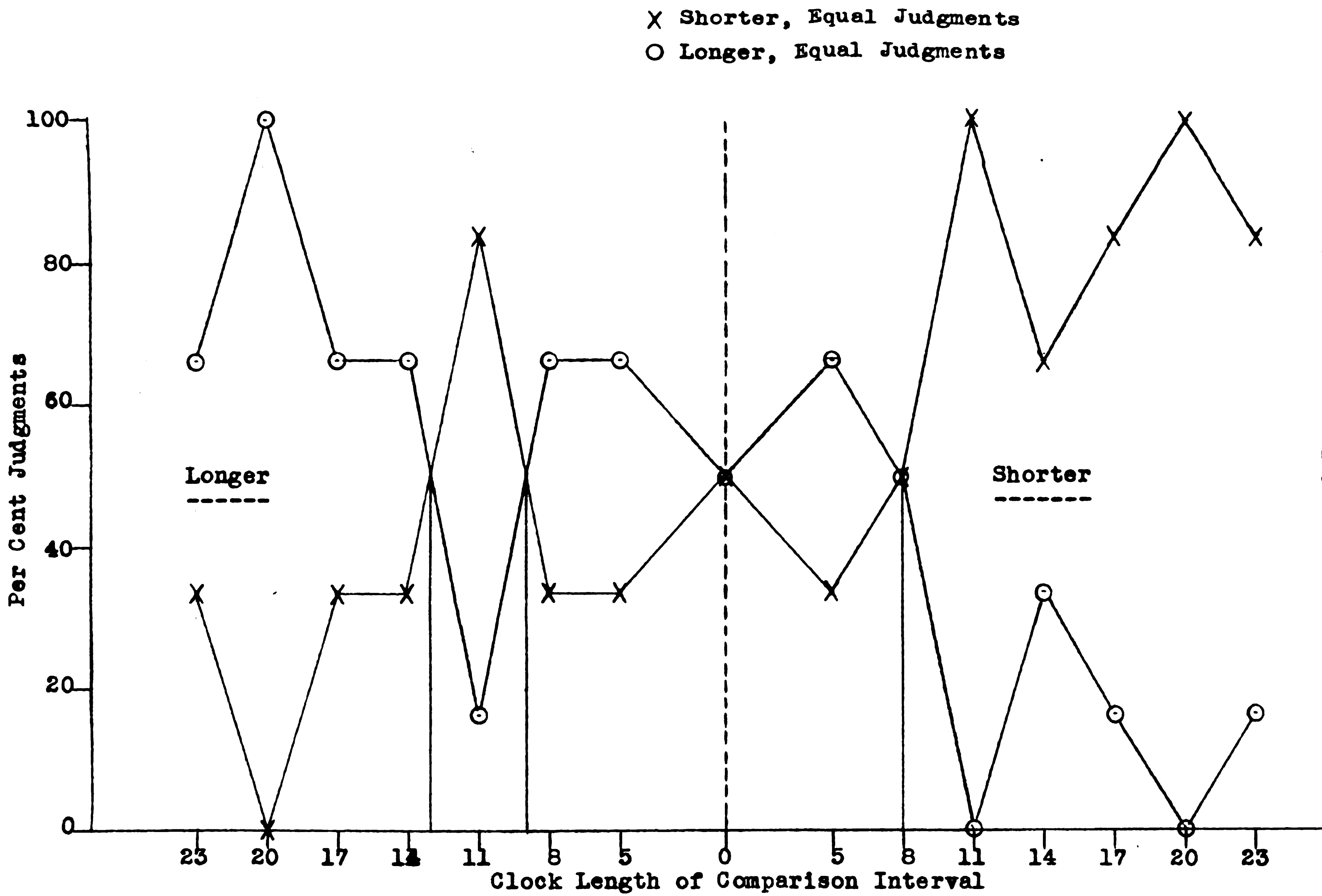

Figure 35. The experimental phenomenal movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval the whole system of phenomenal movements was continuously decelerated at a rate of 2/3 miles per second. 90 comparisons were made to fix the function.

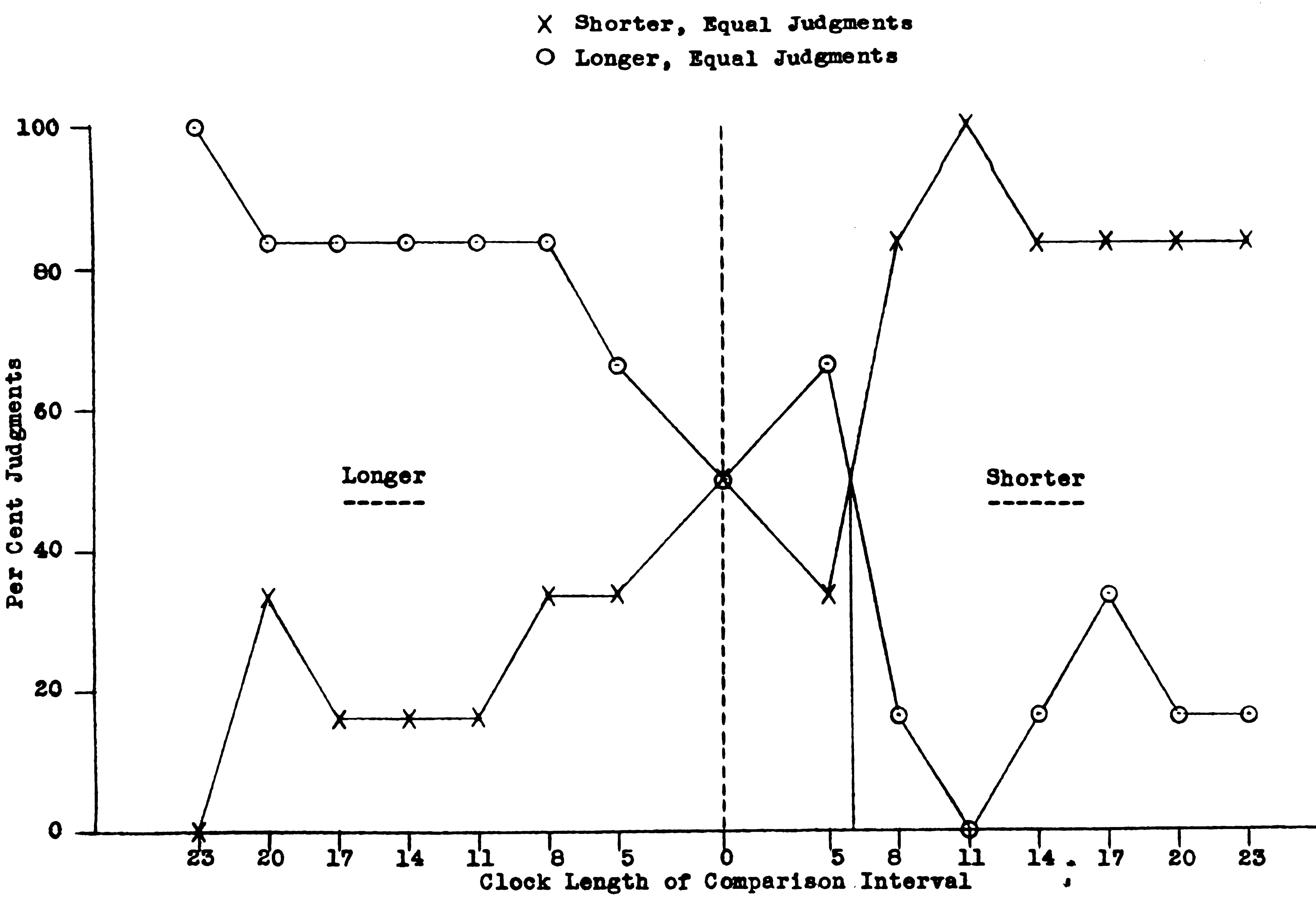

Figure 36. The experimental phenomenal movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval the whole system of phenomenal movements was continuously accelerated at a rate of 2/3 miles per second. 90 comparisons were made to fix the function.

Experiment 16.

Some of the prior experimentation, i.e. experiments 14A, 14B, 15, have suggested that a phenomenally continuous increasing or decreasing system of movement is not readily experienced as having a well defined phenomenal duration. This experiment is a further research into the experienced endurance of complex systems of movement. In experiment 16, relatively brief and rapid increases and decreases will be introduced into an otherwise stable system of phenomenal movement.

Subjects: A total of 6 subjects were used. Four were male and two female. Of this total, 5 were college students and 1 a housewife in middle years. All were naive respecting the purposes of experimentation.

Apparatus: The apparatus was the same as that described in experiment 9.

Method: The method of comparison was used and the standard interval always occurred first. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between experimental pairs. Three category comparisons were permitted.

The standard was exposed for 90 seconds and held at a steady phenomenal movement rate of 2 for a half of the trials and at a steady rate of 12 for the other half. The comparison interval differed from the standard in several ways. First, with respect to clock length, the comparison was 0, 5, 8, 11, 14, 17, 20 or 23% longer or shorter than the standard interval. Secondly, with respect to rate, the standard intervals starting at 2 and 12 were paired with comparison intervals in which there was a reciprocating phenomenal movement. Specifically, the movement was changed continuously from point 2 to point 12 and after a brief pause from point 12 to point 2, and after a brief pause from point 2 to point 12 again for one half of the presentations. The other half of the presentations were paired with comparison intervals in which the movement was started at 12 and decreased to 2 and after a brief pause increased from 2 to 12, and after a brief pause decreased from 12 to 2 again. Thus each comparison interval contained either 2 increasing and 1 decreasing or 1 decreasing and two increasing systems of phenomenal movement. The increases and decreases were fairly rapid, about one point of the phenomenal scale per second. The increases and decreases did not occur consecutively, but were spaced throughout the comparison interval.

A total of 180 comparisons were made. All presentations were made according to a random series. The schematic representation of Table 7 can be used as a model for experiment 16.

<u>Results</u>: Figure 37 contains a plot of all the observations. Figure 38 summarizes the comparisons made when the

standard interval was set at 12. Figure 39 summarizes the comparisons made when the standard was set at 2.

All three figures show that a large range of clock lengths will yield comparisons of equality. It is more fitting to speak of a zone than a point of phenomenal equality under these experimental conditions. The figures, especially 38, show periodic reversal of direction. These fluctuations seem to be of too large a magnitude to be accounted for by chance factor.

Conclusions: The findings of experiment 16 using reciprocating movements confirm all the conclusions drawn from experiment 15. It would seem that as the phenomenal movement increases in complexity, it becomes increasingly more difficult to characterize as a well-defined endurance.

Table 7

A SCHEMATIC REPRESENTATION OF THE METHOD FOLLOWED IN EXPERIMENT 16

Rate of phenom. mvment.	Standard / Comparison	2 Ascend.*	2 Descend.**	12 Asc.	12 Desc.	total cases
Length of inter-val.	Standard	90	90	90	90	
	Comparison	+23%	+23%	+23%	+23%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+20%	+20%	+20%	+20%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+17%	+17%	+17%	+17%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+14%	+14%	+14%	+14%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+11%	+11%	+11%	+11%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+8%	+8%	+8%	+8%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	+5%	+5%	+5%	+5%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	0%	0%	0%	0%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-5%	-5%	-5%	-5%	
	cases	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-8%	-8%	-8%	-8%	
	cases	3	3	3	3	12

Table 7 (Continued)

Rate of phenom. mvt.	Standard / Comparison	2 Ascen.	2 Desc.	12 Ascen.	12 Desc.	total cases
Length of inter- val	Standard	90	90	90	90	
	Comparison	-11%	-11%	-11%	-11%	
	cases.	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-14%	-14%	-14%	-14%	
	cases.	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-17%	-17%	-17%	-17%	
	cases.	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-20%	-20%	-20%	-20%	
	cases.	3	3	3	3	12
	Standard	90	90	90	90	
	Comparison	-23%	-23%	-23%	-23%	
	cases.	3	3	3	3	12
Total cases....		45	45	45	45	180/180

* The designation "ascending" means that the movement during the comparison interval started at rate 2, went to 12, then from 12 back to 2, and finally from 2 to 12 again. See the text for a more complete description.

** The designation "descending" means the opposite pattern prevailed. The rate was from 12 to 2, then 2 to 12, and finally from 12 to 2 again during the comparison interval.

*** The comparison interval is expressed in terms of percentages "longer" and "shorter" than the standard interval.

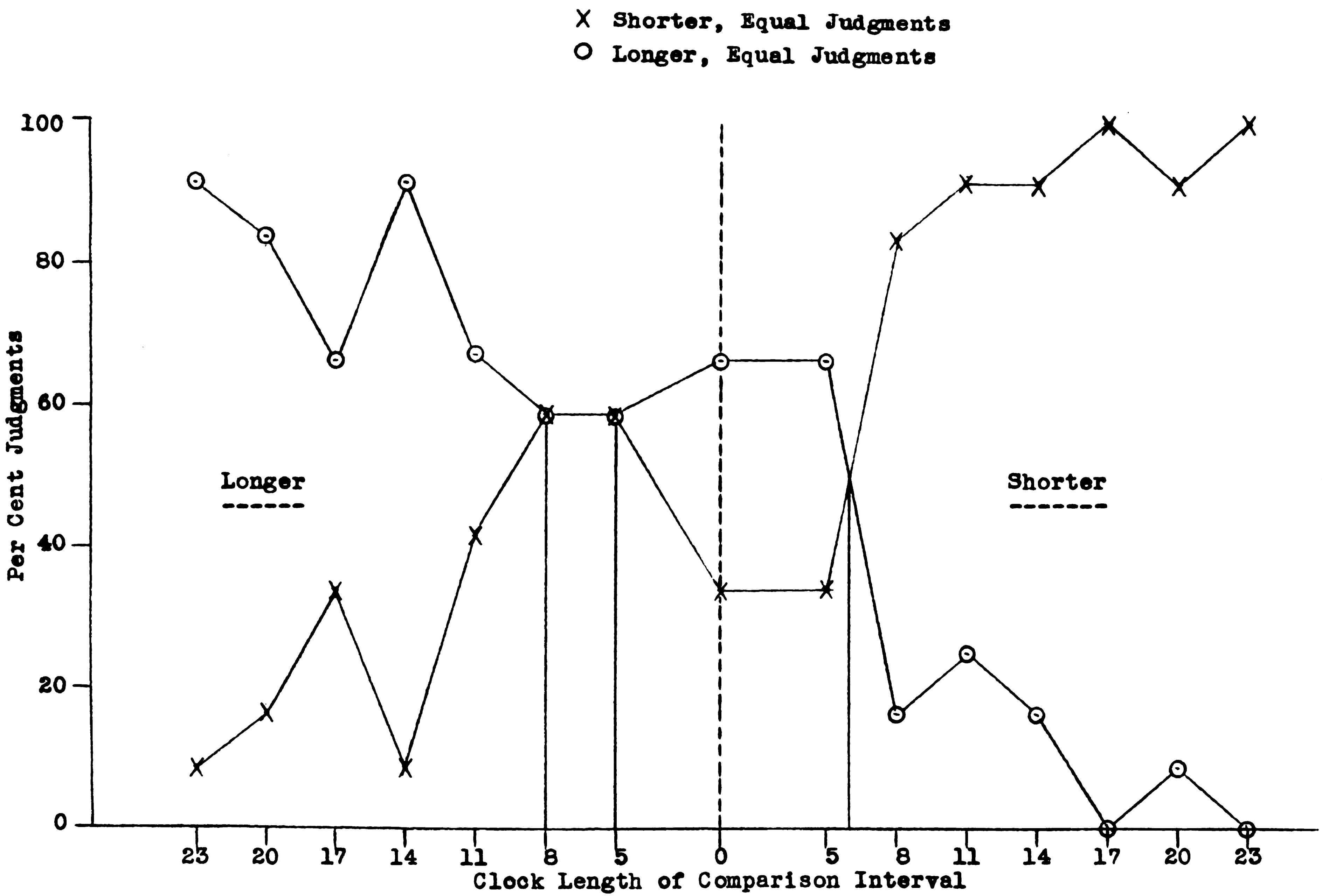

Figure 37. The experimental phenomenal movement standard interval was fixed at a moderately rapid rate (scale point 12) or at a moderately slow rate (scale point 2) for 90 seconds. During the comparison interval the whole system of phenomenal movements was continuously decelerated and accelerated three times for a brief interval. The rate of continuous deceleration and acceleration was very rapid; at 5 miles per second. There were 180 observations made to fix the function.

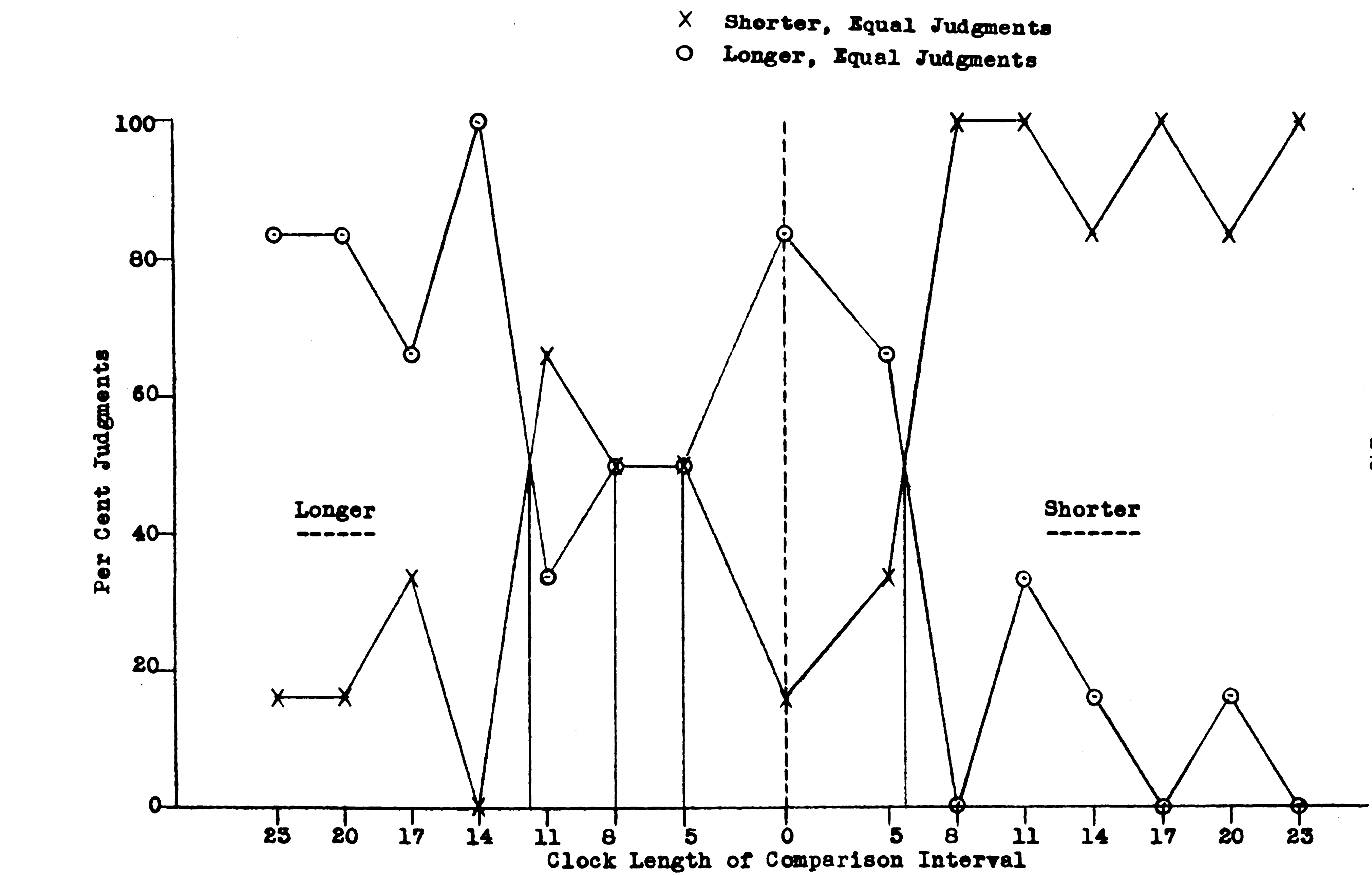

Figure 38. The experimental phenomenal movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval the whole system of phenomenal movements was decelerated and accelerated 3 times for a brief interval. The rate of acceleration and deceleration was very rapid; at 5 miles per second. There were 90 observations made to fix the function.

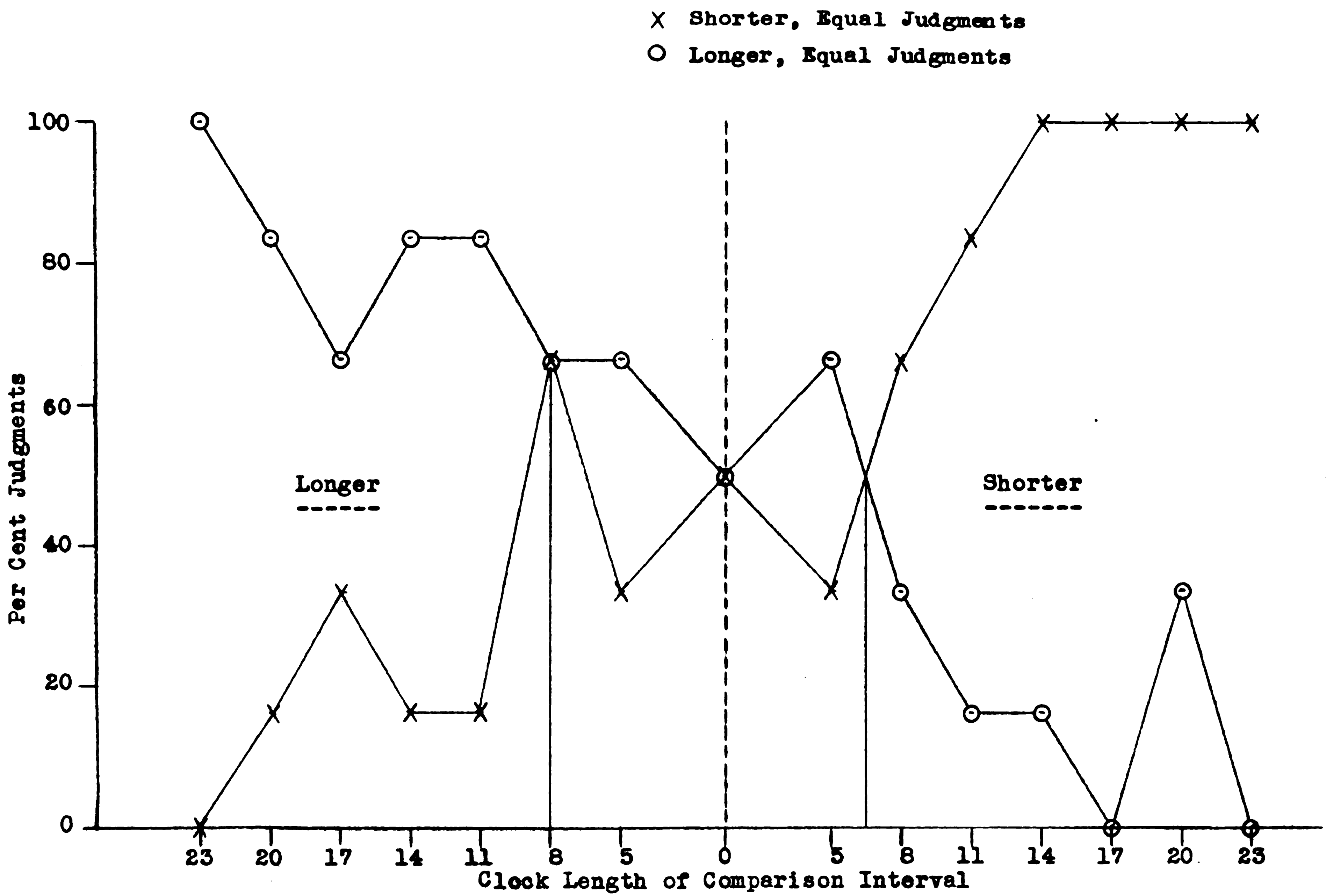

Figure 39. The experimental phenomenal movement standard was fixed at a moderately slow rate (scale point 2) for 90 seconds. During the comparison interval the whole system of phenomenal movements was accelerated and decelerated 3 times for a brief interval. The rate of continuous acceleration was very rapid; at 5 miles per second. There were 90 observations made to fix the function.

The Experienced Duration of Various Phenomenal Changes into which Continuities Have Been Introduced.

Experiment 17.

Purpose: The data of experiment 8 demonstrated that the duration of a changing event is greatly affected by the rate at which it changes phenomenally. The results of experiments 14, 15, and 16, on the other hand, indicated that dissimilar systems of movement are not easily compared as durations. Experiments 15 and 16 in particular indicated that complex movements are even more difficult to compare as duration than are systems of simple movement.

In experiment 17, the aim is to study the experienced duration of a complex containing both change and movement. Specifically, this experiment will study the endurance of phenomenal change events into which continuities are introduced.

Subjects: A total of 5 subjects were used; 4 were male and 1 female. All subjects were college students and all were naive to the purpose of the experimentation.

Apparatus: The apparatus used was identical to that described in experiment 3.

Method: The method used was identical to that employed in experiment 16 except that phenomenal changes were substituted for the phenomenal movements. Table 7 can be used

as a schematic representation of the experiment providing the words "change" are substituted for "movement" wherever the latter refers to the standard interval.

Results: Figure 40 is a plot for the total data of the experiment. Figure 41 is a resumè of the responses occurring when the phenomenal change was set at scale point 12 for the standard. Figure 42 is a resumè of the comparisons made when the standard was set at phenomenal change rate 2. All three figures show that a large range of clock lengths will yield comparisons of equality. The place where phenomenal equality occurs is more aptly described as a zone than a point. The functions of all three graphs contain undulations. In this latter respect, it is particularly interesting to note the reversals that occur at the extremes of these functions.

Conclusions: It is clear when we compare the results of experiment 8 to experiment 16 that the introduction of continuity into a changing event lessens the subject's ability to characterize that event as having definite duration. The outcome of experiment 17 tends to substantiate the conclusions previously drawn and again suggests that movement is not easily characterized as having a well-defined duration and that it will be necessary to question the adequacy of those experimental interpretations relating phenomenal movement to phenominal duration.

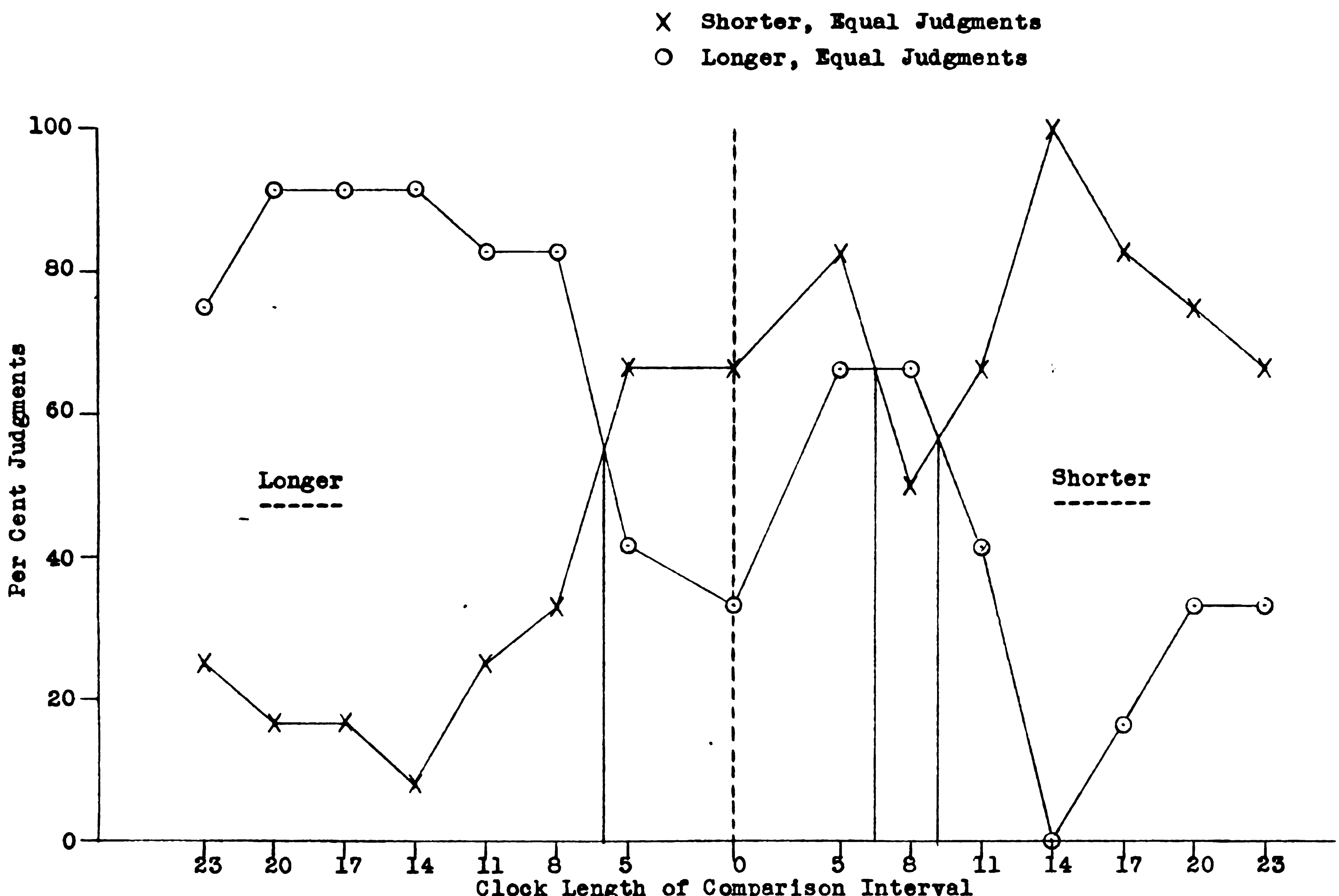

Figure 40. The experimental phenomenal change standard was fixed at a moderately rapid rate (scale point 12) or at a moderately slow rate (scale point 2) for 90 seconds. During the comparison interval the rate of phenomenal change was continuously decelerated and accelerated 3 times for a brief interval. The rate of continuous deceleration and acceleration was very rapid; at 5 miles per second. 180 comparisons were made to fix the function.

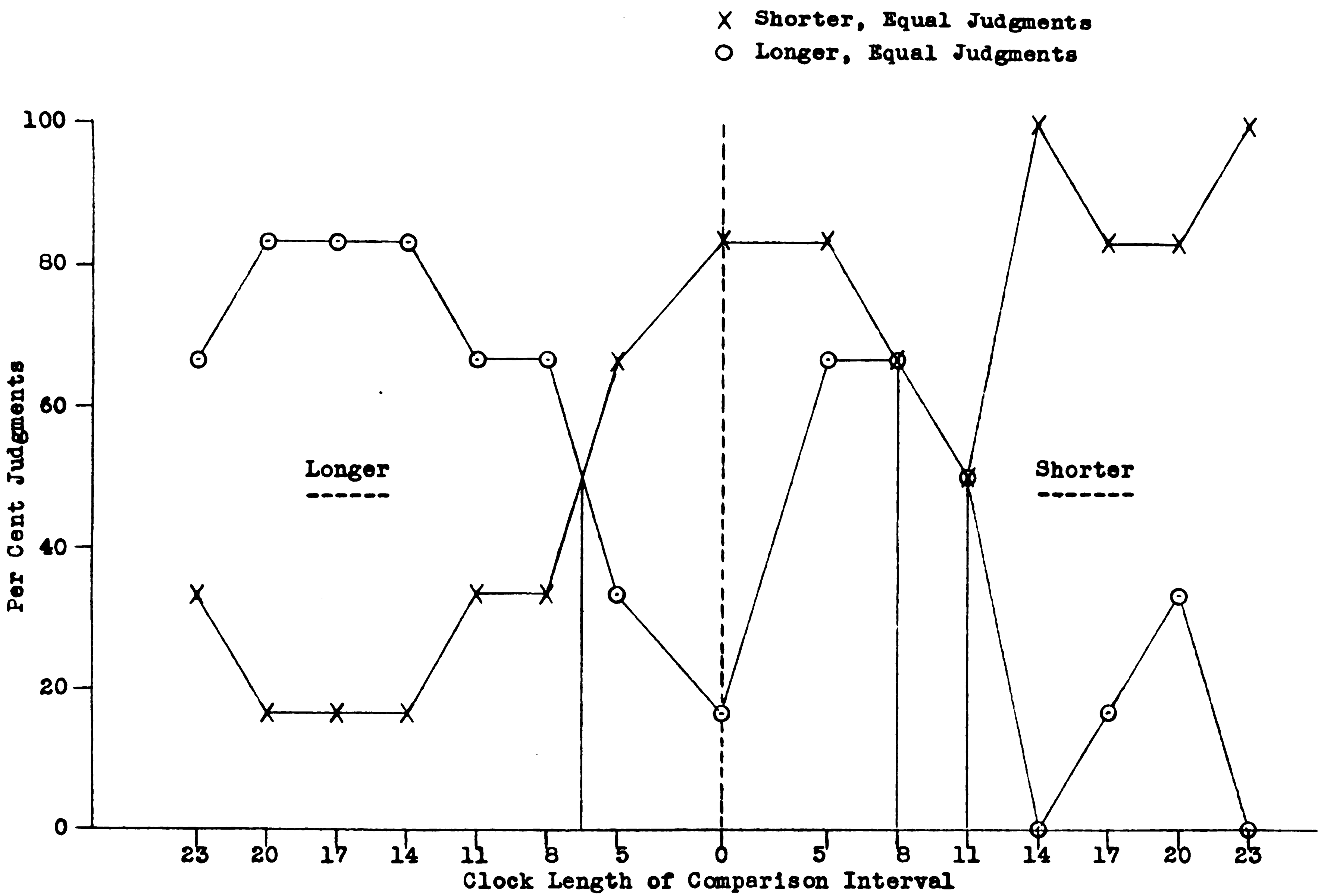

Figure 41. The experimental phenomenal change standard was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval the rate of phenomenal change was continuously decelerated and accelerated 3 times for a brief interval. The rate of continuous deceleration and acceleration was very rapid; at 5 miles per second. 90 comparisons were made to fix the function.

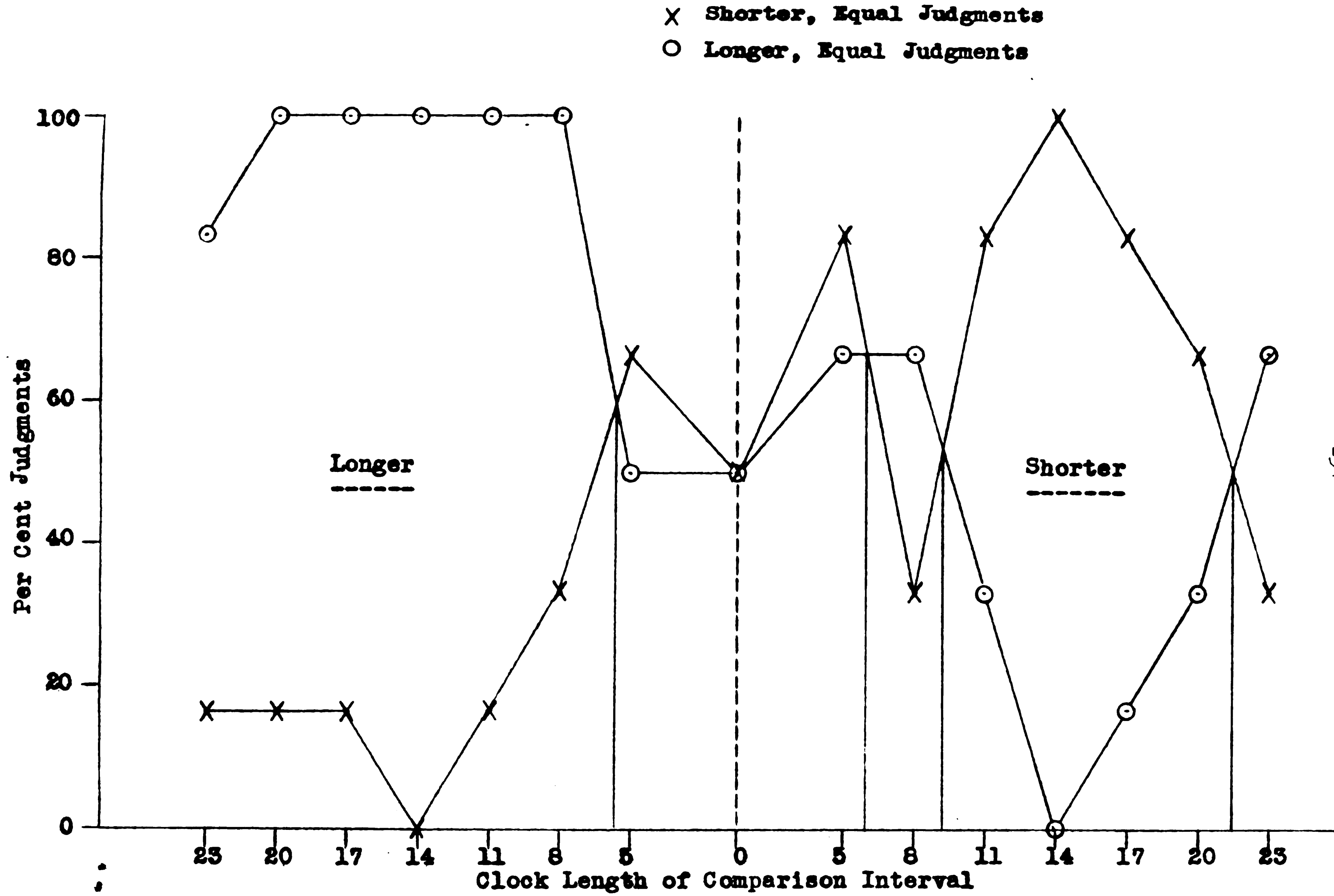

Figure 42. The experimental phenomenal change standard was fixed at a moderately slow rate (scale point 2) for 90 seconds. During the comparison interval the rate of phenomenal change was continuously decelerated and accelerated 3 times for a brief interval. The rate of continuous deceleration and acceleratic was very rapid; at 5 miles per second. 90 comparisons were made to fix the function.

The Experienced Duration of a System of Movement into which changes have been Introduced.

Experiment 18.

Purpose: At this point, it seems justifiable to say that change is more readily experienced as having a duration than is phenomenal movement. It has been experimentally shown that as the system of movement becomes increasingly more complex that at the same time the system becomes increasingly difficult to express as a definite duration. Moreover, experiment 17 demonstrated that when continuities are introduced into a changing phenomenal event that that event becomes difficult to experience as a definite duration.

In experiment 18, the procedure will be reversed and the effect of introducing change into a system of movement will be studied. If the conclusions drawn in previous experimentation are adequate summaries of the facts then this procedure should cause the system of movement to become more identifiable as a duration.

Subjects: A total of 9 subjects were used, 3 female and 6 male. All were college students and naive to the aims of experimentation.

Apparatus: The apparatus was identical to that described for experiment 14.

Method: The method of comparison was used and the standard interval always occurred first. The experimenter attempted to allow 7 seconds between the standard and comparison intervals and 15 seconds between experimental pairs. Three category comparisons were allowed.

The standard was a constant stimulus,always 90 seconds in length and always set at rate 12 on the phenomenal movement scale. The comparison intervals differed from the standard interval in two ways. First, with respect to rate, in 90 presentations the comparison intervals were started at an arbitrary point on the scale and continuously increased at the rate of 1/3 miles per second. In another 90 presentations, the comparison intervals were started at an arbitrary point on the movement scale and decreased at the rate of 1/3 miles per second. These increases and decreases of rate are too slow to be experienced as continuous accelerations or decelerations and instead produce regular and abrupt shifts either up or down in the phenomenal movement system. Secondly, with respect to clock lengths, the comparisons were either 0, 5, 8, 11, 14, 17, 20 or 23% longer or shorter than the standard.

A total of 180 comparisons were made. The experimental pairs were presented according to a randomized order. Table 8 can be used as a schematic representation of the method used providing the words "phenomenal change" is substituted for the words "phenomenal movement" when the latter refer to the comparison interval.

Procedure: The procedure was identical to that described in experiment 14.

Results: Figure 43 is a resumé of all of the comparisons made in experiment 18. Figure 44 summarizes the comparisons made when the abruptions resulted in slower systems of phenomenal movement. Figure 45 summarizes the comparisons made when the abruptions introduced led to a more rapid system of phenomenal movement. Phenomenal equality occurs at a point in all three figures. The functions are fairly constant in direction. A comparison of figure 44 with figure 45 indicates that intervals which contain abruptions leading to increased rates of movement are experienced as being longer in duration than those in which abruptions lead to slower systems of movement.

Conclusions: Experiment 18 indicates that imposing abruptions upon a system of movement enhances the subject's ability to recognize the event as having a definite endurance. The results again suggest that it is change rather than continuity that gives events their endurance. The results in addition suggest that abruptions which increase the activity within an endurance result in that endurance being experienced as longer than when the abruptions lead to a decrease of activity within the duration.

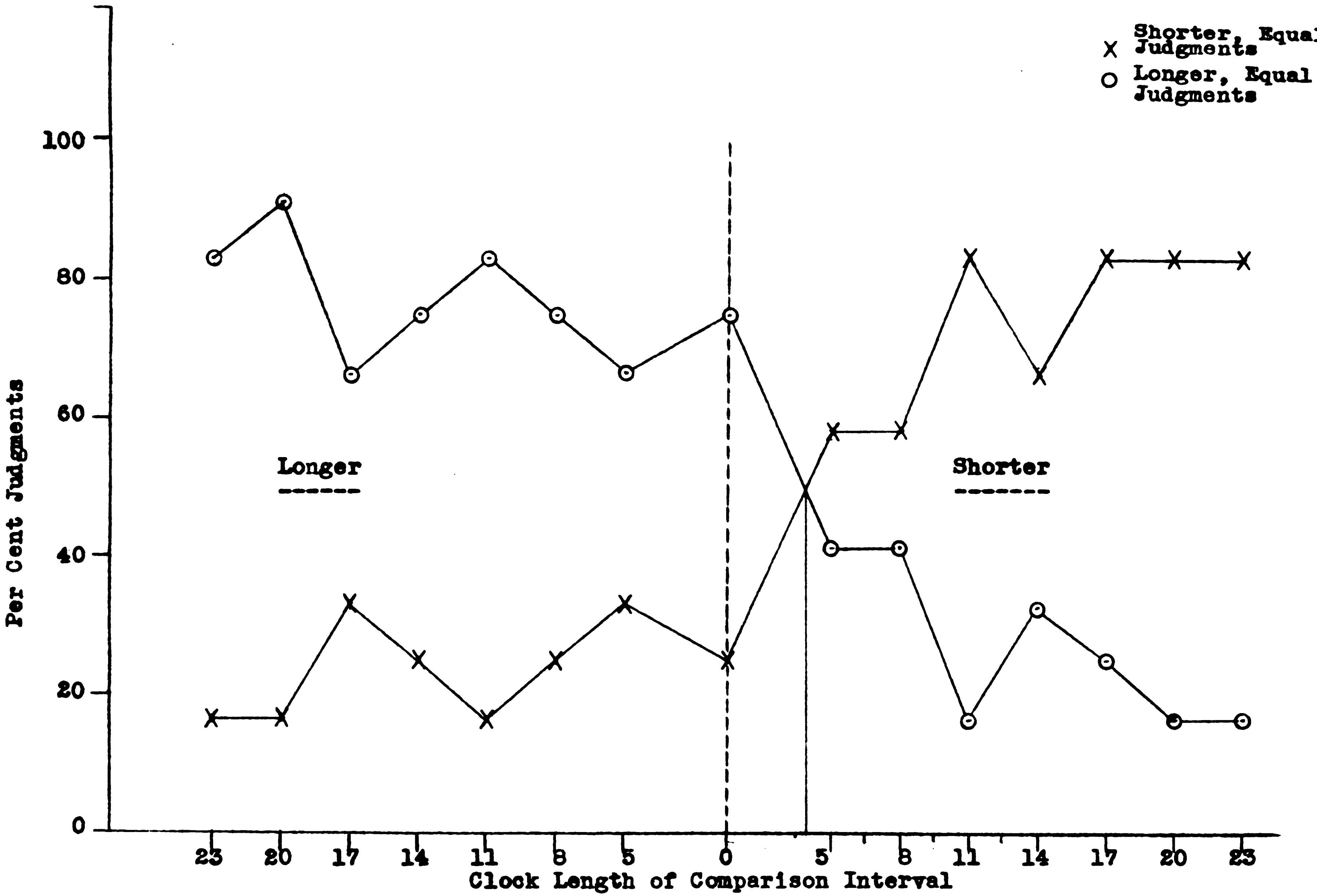

Figure 43. The movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval abruptions were introduced into the system of phenomenal movements by continuously decelerating or accelerating at a rate of 1/3 miles per second. 180 comparisons were made to fix the function.

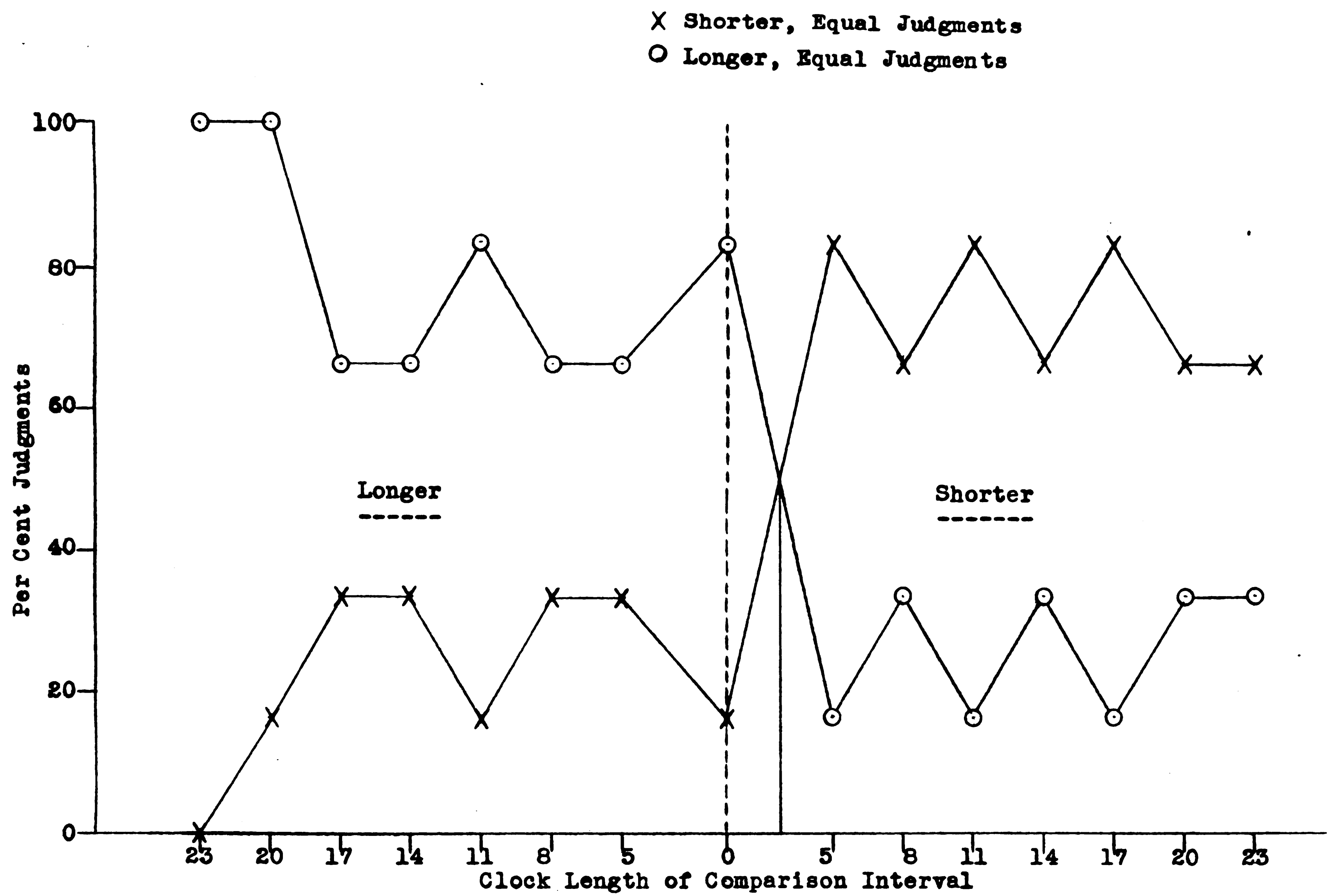

Figure 44. The experimental movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval abruptions were introduced into the system of phenomenal movements by continuously decelerating at a rate of 1/3 miles per second. 90 comparisons were made to fix the function.

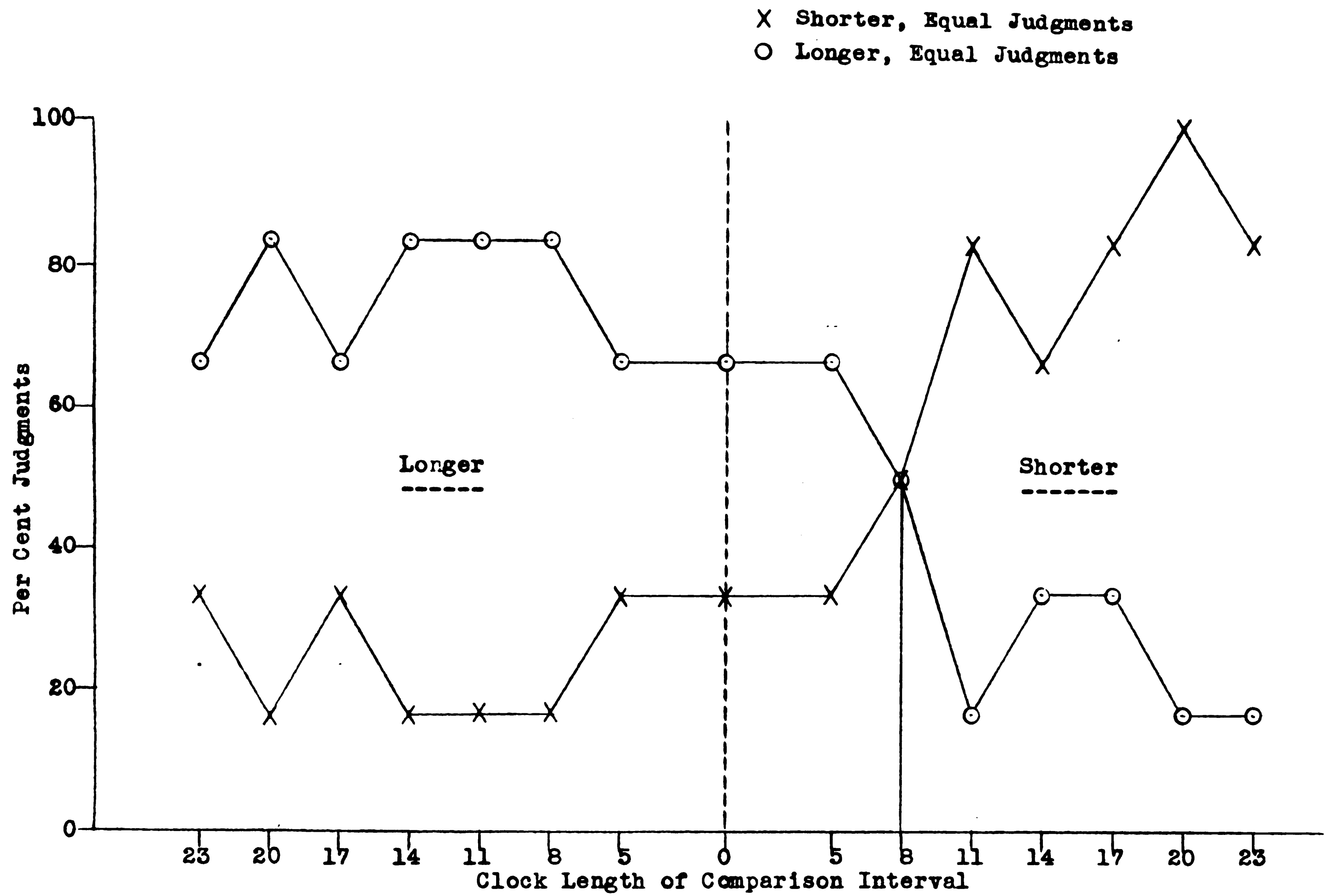

Figure 45. The experimental movement standard interval was fixed at a moderately rapid rate (scale point 12) for 90 seconds. During the comparison interval abruptions were introduced into the system of phenomenal movements by continuously accelerating at a rate of 1/3 miles per second. 90 comparisons were made to fix the function.

CHAPTER IV

GENERAL CONCLUSIONS,

A Theory of Phenomenal Duration, and Reevaluation of Previous Experimentation

GENERAL CONCLUSIONS

The preceding research aimed to provide two things. First it aimed to provide a means for producing, measuring, and controlling phenomenal change, duration and movement. We will appraise the success of this work by considering: a) the general experimental findings regarding phenomenal change, movement and duration; and b) the general findings in light of our hypothesis. Second, it aimed to provide a general understanding of phenomenal duration, change and movement. Toward this end, we will a) issue several broad and more or less acceptable generalizations regarding phenomenal change, movement and duration; and b) discuss the general findings in light of previous research work.

Producing, Measuring, and Controlling The Phenomenal Variables

Phenomenal Change: The production of phenomenal change was accomplished through invention and use of a kalaidoscopic change instrument. This instrument was equipped with a variable speed clutch and ttachometer. The clutch allowed the experimenter to achieve and maintain steady rates of change within wide limits and allowed the introduction of additional changes or continuities into the existing pattern of changes.

The **tachometer** served to indicate the presence of a particular phenomenal change, and also, after the scaling was completed, to indicate its phenomenal magnitude. The means of measurement used was the psychophysical method of limits (minimal change). This means was used because it allows one to characterize human experience as a continual phenomenal distribution. The measurement undertaken in Experiment 1 resulted in a phenomenal change scale of 16 points. Hence, a means for production and a phenomenal scale featuring interval measurement are present, and these indicate that the basis for controlled phenomenal change is also present.

Phenomenal Movement: The phenomenal movements were produced and measured by devices completely analogous to those described above. The measurement made in Experiment 2 resulted in a phenomenal movement scale of 18 points. Hence, a means for production and a phenomenal scale for interval measurement are present, and these indicate that the basis for controlled phenomenal movement is also present.

Phenomenal Duration: Production of phenomenal duration was accomplished by means of the phenomenal change and phenomenal movement apparatus, a shutter device, and through use of a timing clock. The phenomenal change and phenomenal movement apparatus allowed the experimenter to generate durations comprised of many types of visual changes and movements.

The shutter device allowed the experimenter to create well-defined intervals or different clock lengths. The timing clock permitted the experimenter to renew a particular phenomenal duration, and to express, in a non-phenomenal sense, the magnitude of the duration once it was measured. The measurement was based upon a psychophysical procedure distinct from that used for phenomenal change and movement. The means employed was a modification of the "method of constant stimuli", and named the "method of comparison". The method of comparison provided a physical ratio scale and not a phenomenal interval scale to express phenomenal events. The method allowed measurement of phenomenal durations in terms of experienced deviations ("longer" or "shorter") from a single standard phenomenal duration, the 90 sec. clock length interval.[1]

These phychophysical scales do not give a basis for measurement of phenomenal duration in terms of other phenomenal events and for this reason the potential control is of a different sort that provided for the phenomenal change and movement variables. Hence from a phenomenalogical viewpoint these psycho-physical scales can be expected to lead to phenomenal duration control of a very gross sort and one must

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1 In our experimental method, the standard interval always occurred first and the comparison interval second. This was a modification of the "method of constant stimuli" since in the traditional psychophysical method the standard interval occurs randomly. As we were not concerned with the psychophysical problem, the definition of the "stimulus", we could do this and reduce the number of observations necessary appreciably. Hence, the directions always specified that the second presentation was to be compared to the first and that the first was a "standard" duration.

conclude that the possibilities of phenomenal duration control are greatly inferior to those of phenomenal change and movement.[2]

<u>Mode of phenomenal duration control and the hypothesis</u>: The bulk of the research just reported had to do with the effect of phenomenal changes and movement upon phenomenal duration. We were seeking to control phenomenal duration. We were seeking to control phenomenal duration independently of clock time by means of manipulating phenomenal change and movement rates. The results of this research admits of simple summary and provides the test for the two hypotheses suggested earlier.

The experimentation clearly indicates that phenomenal duration control can be achieved by means of phenomenal change control. It has been found that through manipulation of phenomenal change alone, phenomenal duration can be extended or

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2 This shortcoming was inherent in the problem selected. There must be something to scale before any attempt to scale can be practically undertaken. Previous experimentation was far from convincing in this respect. In fact, Woodrow says in his review of "time perception" experiments, "Whether some mental variable such as duration or protensity is an immediate property of our perception or temporal stimuli, or mental processes in general, is a matter of some disagreement."("Time Perception," <u>op</u>. <u>cit</u>., p. 1235). The conflict in experimental conclusions, the utilization of very short intervals and very restricted experimental conditions, the obsession with theoretical problems of introspection or isomorphism, the lack of agreement regarding the indifference interval and time order errors, and the effect of interval length, the presence of unexplained and unreproducable periodicities in duration experience all suggested that the existence of functional connections between phenomenal change and phenomenal movement on the one hand, and phenomenal duration on the other, might be doubted.

contracted and hence, controlled independently of clock length. This conclusion has been drawn on the basis of the following facts:

1. The interval of phenomenal equality was different when the phenomenal durations were based upon rapid rates of phenomenal change as compared to slow rates of phenomenal change. These differences seem to be stable (Exp's. 4, 8).

2. The introduction of phenomenal changes into a phenomenal system known to have a poorly defined phenomenal duration resulted in a well-defined phenomenal duration (Exp. 18). (The introduction of a phenomenal change led the change to be attended to or selected out by the subject at the expense of movement. The brief discreet impressive series of changes emerge so to speak as "figure" while the longer, less discreet phenomenal movement receded as "ground" and duration was "gained").

Thus, in the terms originally used in exposition of the problem, one would say that, "The for-me endurance of an externally localized event is ascertainably determined by the rate at which that event is changing." In crude common sense terms, one would say that a vigorously changing situation "seems to make time go by faster" than a languorously changing situation. The hypothesis that "phenomenal duration varies with phenomenal change" has been confirmed.

The experimentation strongly suggests that phenomenal duration control cannot be achieved by means of phenomenal movement control. This conclusion has been made on the basis of the following specific facts:

1. The interval of phenomenal equality was unstable when the phenomenal durations were based on phenomenal movements, i.e. rapid systems of movement were not reliably different than slow systems of phenomenal movement. Specifically: a) Slight alterations in methodology reversed the effects of ropid versus slow systems of phenomenal movement (Exp's. 10, 14a, 14b). b) Reversals in the interval of phenomenal equality occurred when phenomenal durations of rapid systems of movement were compared to slow systems of phenomenal movement, and vice versa (Exp's 14a, 14b, 15, 16, 17). These multiple intervals of phenomenal equality occurred when analogous experiments using phenomenal change had shown clear cut effects (Exp. 8, 18). c) The reliability of comparisons did not increase as the sample size and disparity between rates of movement were increased (Exp. 14a, 14b).

2. The comparisons became more variable, the zone of phenomenal equality tended to increase, as the complicity of movement was increased from standard to comparison interval (Exp's 12, 14a, 14b, 15, 16).

3. The introduction of phenomenal movement into a phenomenal change event known to have a well-defined endurance

resulted in an ill-defined endurance (Exp. 17). (The sudden introduction of movement as attended to or selected out by the subject at the expense of change. The brief discreet impressive continuity emerged so to speak as "figure" while the longer less discreet phenomenal change receded as "ground" and duration were "lost".) This outcome is in direct contrast to the experiment in which phenomenal movements were interrupted by change (Exp. 18).

Thus, in the terms originally used in exposition of the problem, one would say that, "The for-me endurance of an externally localized event is not ascertainably determined by rate at which the event is moving." In common sense terms, one would say that phenomenal movement tends to be adurational. <u>The hypothesis that "phenomenal duration varies with phenomenal movement" has not been confirmed</u>.

<u>Qualitative Characteristics of Phenomenal Duration Control</u>: It was found that not all subjects were able to make the comparison required of them. Two subjects could not use either duration present as the standard. They could only report which of the two durations was the "longer". Apparently the presentations formed a single event which could not be referred to other than as polarities. Two other subjects were able to use only the second as a standard presentation..They reported that the later duration was more "fresh" and "asserted itself" so clearly as a "standard" that the earlier duration was bound to be measured by it. These findings are in

substantial agreement with the findings of Benussi and Kastenholz summarized by Woodrow.[3]

Protocols such as these emphasize the necessity of ascertaining the subject's approach to the task before proceeding to collect data on phenomenal duration. Introspective reports, given after several comparisons have been made, prove indispensable aids in controlling for work habits.

Theory of Phenomenal Duration.

Up until now the facts uncovered have been discussed and organized in terms of the two hypotheses. This is the most restricted way in which the findings may be used. In the present case the functional dependencies established appear to be sufficiently consistent and numerous to justify an interpretation extending beyond the "region of hypotheses." Thus, at this point the facts will be put into a theoretical context. This theory will be called the Theory of Phenomenal Duration. The theory, as any other, will find justification only so long as it is rigorously in accord with definite empirical data, provides an acceptable organization of other related data, and is fruitful of further hypotheses. Inasmuch as this is so, the most immediate task is to establish the theory within the realm of well-defined fact.

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3 H. Woodrow, "Time Perception," *op. cit.*, pp. 1227-1228.

Statement and Evaluation of Theory: The usual scientific interpretation of experienced duration utilizes "time" concepts of some sort. Theorization on this basis will be avoided here because, as we have seen, mankind is largely confused about the nature of time. Time concepts would introduce an indefensible weakness into the theory. The theory will be constructed on a basis that is entirely observational.

Starting with only phenomenal facts present in the experiments just conducted, it seems possible to state that the experience of duration is a predicate of phenomenal change but not phenomenal continuity. The facts indicate that phenomenal continuities tend to be durationless although extended in phenomenal space. These facts are:

1. All the facts reviewed in the section titled "Mode of Phenomenal Duration Control."

2. The fact that all of the phenomenal change and movement intervals had to be founded by change to become durations. Had not the phenomenal change and movement intervals occurred and ceased, there would not have been durations available for comparison. The on-off changes provided the condition for the existence of duration. As will be seen later, this basic fact can account for whatever and all duration phenomenal continuities possess. The entire endurance of continuities per se appears to be given by their onset

(the recognition of their existence) and offset (realization that continuity no longer exists).

3. The fact that the ratio of "long" to "short" comparisons was 1.00 to .55 respectively for both phenomenal durations of phenomenal change and movement when the control of the variables was such as to lead to a prior prediction of equal occurrence (Exp's. 3, 9). Since the judgments can not be attributed here to differences between the intervals being judged, it is possible that the impression results from a comparison of the standard and comparison intervals to factors within the experimental setting itself. If this is the case, the results are as might be expected since the standard and comparison intervals to factors within the experimental setting itself. If this is the case, the results are as might be expected since the standard and comparison intervals embody a more rapid rate of change than the "dead" laboratory situation.[4]

4. The fact that phenomenal change intervals produced a larger bias toward the "longer" end than phenomenal movement intervals when the change and movement experiments were analogous. A breakdown of the differences between Experiments 3, 4 on the one hand and Experiments 9, 10 on the other, show fairly large differences in this regard. The ratio of "long" to "short" is 1.00 to .64 and 1.00 to .88 respectively. Since

4. Previous experimenters have suggested that this biasing in general is due to feelings of "strain" or "anticipation". Ibid., p. 1229.

the phenomenal movement durations yield less biasing toward the "long" end than the phenomenal change durations, it indicates a "loss of endurance" for the movement condition relative to the phenomenal change condition.

5. The fact that the data from phenomenal movement experiments 11 and 12 resulted in typical phenomenal change curves (In Figures 22, 23). The points of phenomenal equality are clear and the biasing that occurs is toward the long end unlike all other phenomenal movement functions where clock length is varied). The typical change results are to be expected when one realizes that the movement condition provided edge changes as the colors entered and left the screen. The longer the clock length of the movement interval, the greater the magnitude of edge changes produced and, hence, the "longer" the experience of duration, while the shorter the clock length of the movement interval, the less the magnitude of change provided and the "shorter" the experience of duration. (The edge changes are ordinarily inconsequential, but with movement held constant and clock length varied, differences in the magnitude of phenomenal change is produced.)

There are no facts within the 20 experiments reported which seriously threaten the adequacy of the theoretical statements made.

Theoretical Reinterpretation of Prior "Time Perception" Experimentation [5]

The introspection experiments of Vierordt, Kollert, Estel, Mehner, Mach, and Meuman demonstrated that definite differences in comparison can be expected to follow definite differences in interval "filling". Gestalt-oriented psychology provided experimentation by Korte, Senussi, Husler, Kastenholz, Desilve, Brown, Cartwright, Hansel, Cohen, and Sylvester, in which definite differences in comparison followed definite differences in field factors such as distance and velocity of movement, and attitude. Even though this abridgement omits from consideration numerous contributions of various "uncommitted" investigators, the results are impressive. Hence, the introductory statement from Woodrow's chapter "Time Perception" in Steven's Handbook to the effect that the outstanding characteristic of prior research is "...the conflicting nature of the findings" is not quite accurate. Woodrow was guilty of immoderation. Woodrow, among other things, overlooked two important things:

1. The fact that experimentation has consistently provided psychology with the means for production of phenomenal duration.

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[5] This extension of the theory is attended with extreme difficulty since the various factors which we have been dealing with were ordinarily not satisfactorily isolated in the reports given by earlier workers.

2. The fact that the basis for control of phenomenal duration has been present for many years.

What he might perhaps better have said was that prior experimentation failed <u>in fact</u> to control phenomenal duration to any significant degree. Such a restatement is in better accord with the scientific tradition since it provides two fresh questions. These questions are:

1. What is the significance of the differences prior experimentalists obtained between compared intervals?

2. Why did the earlier experimentalists fail in fact to control phenomenal duration when the means of production and measurement were present?

Our reinterpretation, as any other, must be oriented toward providing answers to these two questions.

<u>The Significance of "Filled-Unfilled" Results:</u>[6] Using this technique, two intervals, each formed by two consecutive impingements, e.g. clicks, flashes, pricks, etc., are compared. The intervals are termed "filled" when experimental variables are introduced between the two bounding impingements and termed "unfilled" when nothing but the two bounding impingements are experimentally provided. Hence, one will note that <u>the means of production and measurement of "time perception" using</u>

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6. In answering the first question, we will primarily deal with the research reviewed earlier (Chapter 2). We will assume that these investigations are fairly representative.

the "filled-unfilled" technique is in all basic respects the same as that followed in the phenomenal duration experiments just described since the durations are defined by phenomenal change.

According to the theory, if two intervals, one filled and one unfilled, of equal clock length, should be compared as regards duration, the filled interval should be experienced as being longer than the unfilled since it represents a greater magnitude of phenomenal change. The theory seems to adequately reflect the facts,[7] since:

1. Hall and Jastrow reported that "...with ten clicks, the following interval to be judged equal to it must be extended to the time of 14-18 clicks; 15 seemed equal to the time from 16 to 19."

2. Ejner and Kraeplin reported that unfilled intervals must be continued longer than intervals filled with metronome beats to achieve phenomenal equality.

3. Meuman reported that intervals filled with discontinuous sounds showed a reliable positive constant error, i.e. a biasing toward "longer" comparisons when the discontinuously

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7. In addition, C.S. Myers, the only authority to so review the time perception problem, says that "...when two sound stimuli limit a given interval, and one interval is compared with an equal interval, the error of estimation increasing up to a certain point with the number of sounds filling the interval. This same holds for a visual and still more markedly for tactual stimuli." A Textbook of Experimental Psychology. (3rd ed.; New York: Longmans Green and Co., 1928) p. 297.

filled variable occurs first, for clock lengths around 10 sec. when these are compared to unfilled intervals were unreliably compared to unfilled intervals.

4. Gilliksen reported that intervals of 30 sec. filled with metronome beats are overestimated by clock standards.

5. Roloff and Zeeman reported that intervals containing visual targets periodically interrupted were experienced as "longer" than unfilled intervals.

6. Brown concluded from his data that intervals containing movement were experienced as being longer than unfilled intervals.

Evidence to be considered possibly against the theory is the following:

1. Rosloff and Zeeman reported that a continuously shown visual target is experienced as having a longer duration than a visual target interrupted once during the interval.

2. Meuman reported that the difference in the phenomenal durations of filled and unfilled intervals becomes increasingly smaller and finally disappears as the clock length of the intervals increases.

This agreement is made more impressive when one considers that the short interval studies provide the most difficult test since uncontrolled variations, that under "longer interval" circumstances would be considered to be of minor importance, are bound to loom large in the results.[8]

The Significance of the Apparent Movement Results: In Cohen, Sylvester, and Hansel's study,[9] three light flashes were consecutively introduced at a rate that produced beta movement. The subject's task was to compare the phenomenal duration of the movement produced by the flash of the first and second target, to the phenomenal duration of the movement formed by the flash of the second and third target. Thus, we have in effect two filled (filled by "apparent" movement) intervals which vary in distance of the movement between abruptions. Hence, one will note that the means of producing and measuring durations of apparent movement is fundamentally the same as that used in the "filled-unfilled" and phenomenal duration studies previously discussed, since the durations are being defined by phenomenal change.

The experimenters found that as the distance of (apparent) movement increased, the clock time between flashes had to be decreased to achieve phenomenal equality, i.e. if the movements were disproportionate in distance but equal in clock length, the greater movement would be experienced as "longer."

8. A fine confirmation of this statement and the general theoretical reinterpretation of earlier "duration as an attribute of the stimulus" studies is to be found in : M.L. Nelson's "Visual Estimate of Time" (Psychol. Rev., IX(1902),pp.447-459). This study, which came to the attention too late to be included conveniently in the manuscript proper, used long "filled" and "unfilled" intervals. For a description and brief discussion of this study, see Appendix 1.

9. Cohen, Sylvester, and Hansel, "Interdependence of Space, Time, and Movement," op. cit.

This is what we would expect from the theory since the change in position in this case is of greater magnitude than the change in position when the flashes are close together.[10]

The Significance of the "Real" Movement Results: In Brown's "time perception" experiments,[11] a black target, square in shape, was inked on a continuous belt and the belt rotated at various rates behind a screen into which various shapes and sizes of apertures had been cut. (The reader should note here that the square does not move across a field but that the field moves with the target.) The subjects were seated two meters away and were required to adjust the velocity of the black square seen moving through a bounded field so that the square seemed to have a duration equal to that of a standard "unfilled" interval. The nature of the fields was a primary variable since Brown hoped to show that field factors affecting the values of v would have an inverse effect upon t, i.e. that the equation $v = s/t$ would hold. For this reason some of the crucial field-target situations described by Brown have been drawn to size in

10. Cohen, Hensel and Sylvester's explanation in terms of movement is weak at best, anyway. It is a well-known empirical fact that one cannot manipulate distance and hold other factors experimentally constant without changing the quality of the beta movement. Korte's laws show apparent movement to be a result of a complicated interdependence of conditions. Cohen, Hansel and Sylvester varied distances over an 18" range and nowhere mention controlling for any of these factors. Therefore, it is more than barely possible that the quality of movement was not constant, that is, equally "good", for all distances compared.

11. J.F. Brown, "On Time Perception in Visual Movement Fields," op. cit., pp. 233-248.

Figure 46.[12] Thus, we have in Brown's experiments: a) an unfilled-filled technique since the duration of a phenomenal (real) visual movement is being compared to the duration of a standard interval given by flashes or clicks; and b) a filling being provided by phenomenal (real) movement and the more subtle "field factors". Hence, one should note that the means for production and measurement of "time perception" employed in the "real" movement technique is in important respects the same as those followed in all the previous experiments discussed since the compared durations are being defined by phenomenal change.

According to the theory, the experienced duration of the movement should reflect the magnitude of change it represents. Most of the evidence published by Brown on the basis of his experiments indicates that the theory adequately represents the facts, Particularly:

1. In all cases the moving fields were experienced as having longer duration than did the "empty" intervals to which they were compared. To make certain the reader understands this important finding, let it be put in another way. Every one of the fields pictured in Figure 46, and some not pictured, contained moving black squares. In every case the intervals defined by the appearance and disappearance of these squares constituted a comparison interval. These "filled"

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12. In the duration experiments of Brown, the targets moved upwards rather than to the left as shown when Figure 46 is normally oriented as a page.

intervals were compared to a standard interval which was defined by 2 clicks separated by 2 seconds (the "empty" interval). In all cases the interval "filled" with movement and defined by the appearance and disappearance of the square had to be exposed always somewhat less than 2 seconds (the exposure time was cut by increasing the speed) to produce an experience of equal duration.

Less important evidences in this direction are that:

2. An average of 1.45 seconds of movement (4 subjects) was required in condition A (Figure 46) to match a 2 second "empty" interval when the field was brightly lighted, while 1.78 seconds was required when the same field was dimly lighted. In order to understand why the brighter condition should produce a longer phenomenal duration than a movement in the dimmer field, we need to recall that (a) the ground is in motion as well as the target and that (b) the brightly lighted field will provide for a more pronounced background texture and steeper light gradients at the borders than the dimly lighted field.[13] Since this is so, the texture and target leaving the field bounds will produce progressively greater changes as the field-target situation is brightened because: (a) the borders and texture of the field become progressively more articulated; and (b), the contrast between the moving field with its target becomes progressively greater. Hence, the theory fits the

13. J. J. Gibson, The Perception of the Visual World (Boston: Houghton Mifflin Co., 1950), pp. 77-116.

facts because the greater change accompanying the movement in the brighter field yields an experience of longer duration than an equal length movement in the dimmer field.[14]

3. An average of 1.36 seconds of movement (3 subjects) was required in field D to match the 2 seconds "empty" interval, as against .96 seconds when the width of this field was held constant and the length doubled, as against .52 seconds when the width was constant and the field was quadrupled in length. To understand why the phenomenal duration should vary with the field length, we need only recognize that there was in essence an increase in the magnitude of change in the system as the distance of movement was increased since the same texture and edge gradients are in effect here as in the experiment discussed above. Hence, again we find a general agreement with the theory since an increase in the magnitude of change in the system again has occasioned a consistent increase in phenomenal duration of the movement.

4. An average of 1.46 seconds of movement (3 subjects) was required in field A to match the 2 second "empty" interval,

14. This explanation is rendered even more likely by the fact that Külpes' summary of the early studies of duration includes the statement to the effect that an interval which is bounded by two more intensive sound impressions will be taken to be shorter than identical clock interval bounded by weaker sounds. (op. cit., p. 388). Later work by Woodrow (1928) also lends credence to the theory. For example, when he investigated the influence of duration of the initial and terminal sounds upon estimation of short empty intervals he found that lengthening either the initial or terminal sound caused the interval to be judged longer. ("Behavior with Respect to Short Temporal Stimulus Forms," J. Exp. Psychol., XI(1928),pp.167-193.)

as against 1.16 sec. for field B. It can be seen that field A has double the dimensions of field B while the target remain of constant size. Hence, the findings are in general agreement with the theory since a change of target position in B is of greater magnitude relative to the system than an analogous change in A and since this difference leads to a "longer" phenomenal duration in field B. (We are assuming here that the target has prepotence over the ground, i.e. the texture gradients.)

Minor evidence possibly against the theory are the following facts:

1. An average of 1.74 seconds of movement (3 subjects) was required in field A to match the 2 second "empty" interval, as against 1.66 seconds for field D, as against 1.68 seconds for a field midway between A and D. Since the targets are reduced proportionately from one field to the other, phenomenal change would be equal relative to the systems and one would predict on the basis of the theory that identical values would be obtained under each condition. Hence, the small differences, since they are reliable, seem to stand against the theory. These differences, however, might be accounted for by doubting the assumption that proportional reductions have been in fact made. This doubt is bolstered by the fact that Brown reports that decreases in the physical size of the apertures were not followed by identical decreases in the phenomenal size of the openings.

2. An average of 1.71 second (3 subjects) of movement was required in field A as against 1.95 seconds in field C to match the 2 second "empty" interval. This result seems to run counter to the theory since the duration marked by the targets in condition C would seem to subtend a larger magnitude of change than a similar occurrence in field A. However, there is reason to doubt that we are in fact dealing with analogous systems since the targets in C cannot be clearly distinguished from the border at the distance used for observation.[15]

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15. A recent study by Smith and Sherlock lends support to our contentions. They reproduced Brown's condition for the study of velocity and concluded that the phenomenal velocity of movement was determined by the frequency at which the objects left their bounded fields. Smith, O.M., and Sherlock, L., A New Explanation for the Velocity-transposition Phenomenon, Amer. J. Psychol., 70, 1957, 102-105.

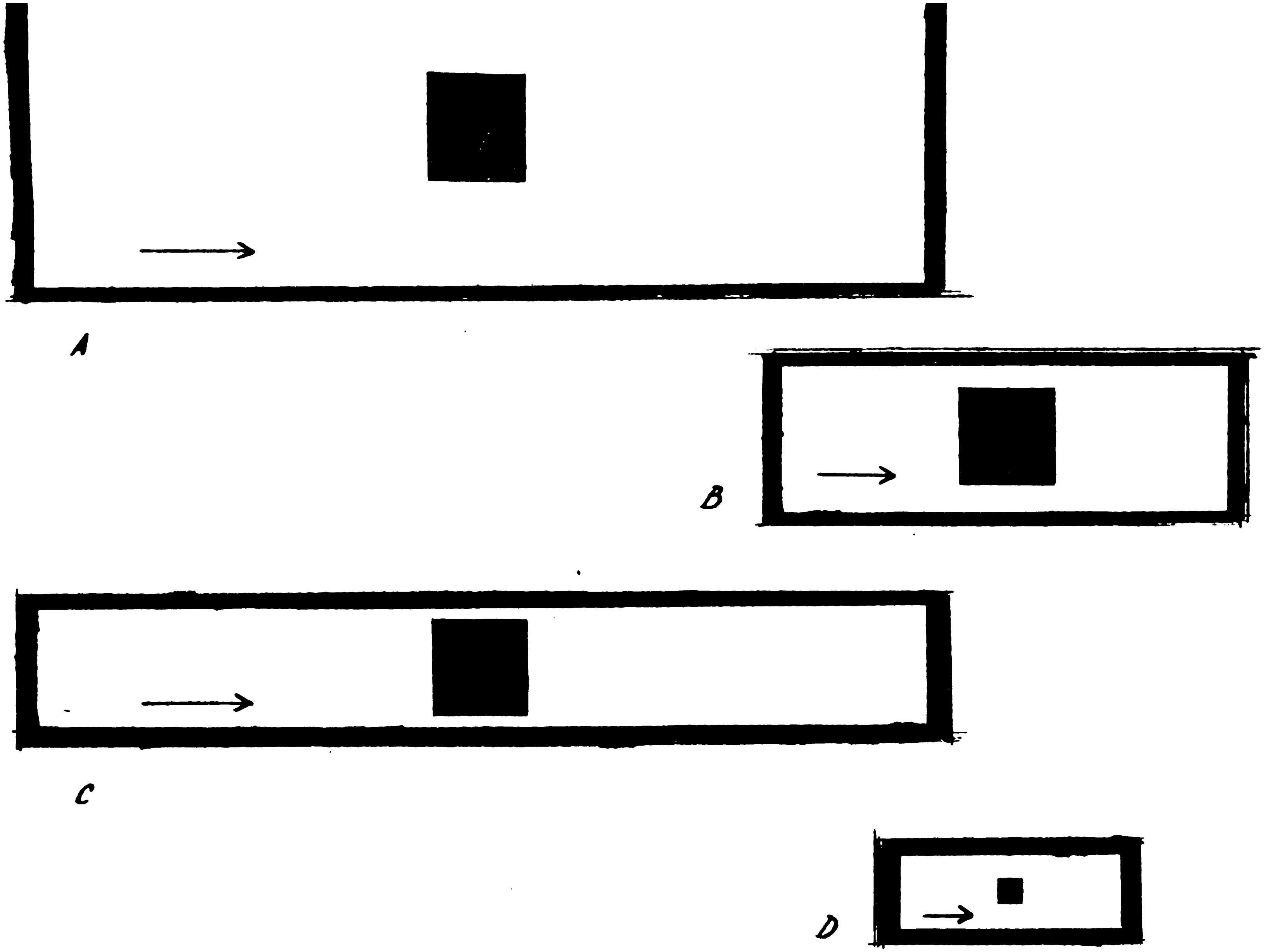

Figure 46. A representation of J. F. Brown's experimental set-up drawn to scale.

<u>Significance of Part Failures of Phenomenal Duration Control</u>: The answer to the question, "Why did the earlier experimentalists fail in fact to control phenomenal duration when the means of production and measurement were present?" Can now be answered. The answer does not lurk too far beneath the surface. The failure appears to be closely related to the psychologists assumptions that "time" is the central and important psychological problem, not phenomenal duration. Speaking bluntly the questions asked seem, at bottom, to have been either,"Why doesn't man behave like a clock?" or "In what way is man like a clock?" The Gestalt oriented psychologist, expounding the thesis of psychophysical isomorphism, sought to demonstrate in the most spectacular fashion possible, the multitude of possible correlations between clock-time on the one hand and experienced durations and field factors on the other hand. These variations of course demanded a particular "dynamic" psychology to explain. The psychologist of introspection on the other hand, questing for mental elements to rebuild experience embraced the second question and searched for a mental unit of "time". On the basis of the facts one might reply to the question in a general way by saying that the failures are rooted in the inability of all concerned to distinguish between problems of psychology and physics, i.e., duration and clock time. This failure, as we have seen, inevitably led to inappropriate investigations, inability to appreciate the significance

of the bulk of experimental data and, consequently, failure to control the relevant variables. The implications of this criticism will become clearer after the relationship between time and duration have been explored. This topic is to be considered on another occasion.

CHAPTER V

SUMMARY

Summary

Surveying the inquiry as a whole we find that it has had a two-fold character. The main consideration has been adequate description and discussion of a complex series of experiments. The secondary consideration has been of a more general nature, namely, that of appraising the overall scope of the problem of phenomenal duration. The secondary problem was closely related to the first however, for by fulfilling the secondary aim we hoped to clarify our position with respect to the problem of duration in a way that would allow for the possibility of a positive, self-sufficient approach to the empirical data. The second problem necessarily received priority in order of treatment.

Adequate definition of the phenomenal variables of duration, change, and movement was the initial problem faced. Inquiry into the various alternatives indicated that:

1. A phenomenal term can be self-sufficient, i.e. refer to a fact, providing that it is possible to recognize the term asserted on an empirical level.

2. Phenomenal duration can not in fact at present be satisfactorily defined in any other way, i.e. neither in terms of time concepts nor in terms of introspective or overt behavior concepts of duration.

3. Adequate definitions of these variables had not been made upon an empirical level.

Once the general possibility of direct phenomenal meaning was allowed for, specific possibilities were posed and the following three definitions were decided upon.

1. Phenomenal duration was taken to mean "the for-me endurance of an external event."

2. Phenomenal change was taken to be "a condition in which some identifiable thing is evolving. In such a condition most of the parts, but not all, are the same on the two occasions of observation."

3. Phenomenal movement was taken to be "a system of things in which the things have a continuity and direction relative to one another. Such a system is totally different upon two occasions of observation."

These empirical meanings were then given operational references.

The experimental problem itself dealt with the possible interdependence between phenomenal change and duration on the one hand and phenomenal movement and duration on the other. Prior research was not, for a number of reasons noted, of much value in framing expectancies concerning the relationship.

Two hypotheses were put to the test. These hypotheses were:

1. Phenomenal duration will vary as a function of phenomenal change.

2. Phenomenal duration will vary as a function of phenomenal movement.

In order to test these hypotheses an instrumental means for producing various phenomenal changes, movements, and durations was necessary. The instruments invented, provided a means for measuring and controlling as well as producing the phenomenal variables.

Nineteen studies were reported in all. In these studies a modified "method of comparison" was used. Considering these studies in order, they concerned:

1. The scaling of phenomenal change.
2. The scaling of phenomenal movement.
3,4,5,6,7. Selection of a standard interval of phenomenal change.
8. A study of the interdependence between rate of phenomenal change and phenomenal duration.
9,10,11,12,13. Selection of a standard interval of phenomenal movement.
14A,14B. Studies of the interdependence between rate of phenomenal movement and phenomenal duration.

15,16. The phenomenal duration of movement systems into which accelerations or decelerations have been introduced.

17. The phenomenal duration of a kaleidoscope when various continuities are introduced.

18. The phenomenal duration of a movement system where various changes are introduced.

The results of these studies lead to the general conclusions that:

1. Phenomenal change, movement, and duration can be produced and measured in experimental situations.
2. That phenomenal change, movement, and duration can be controlled.
3. That one mode of controlling phenomenal duration is via phenomenal change control. <u>This confirmed hypothesis 1</u>.
4. That phenomenal duration can not be effected via control of phenomenal movement. This disconfirmed hypothesis 2.

Generalizing from these results a theoretical statement termed the <u>Theory of Phenomenal Duration</u> was made. This theory stated two things:

1. The experience of duration is a predicate of phenomenal change but not phenomenal continuity.

2. Phenomenal continuities are durationless although extended in phenomenal space while phenomenal changes are both durations and extended in phenomenal space.

The Theory of Phenomenal Duration was then put to the test. It apparently can successfully account for lack of harmony in the results of prior "time perception" studies which used:

1. The filled-unfilled experimental technique.
2. The apparent movement experimental technique.
3. The real movement experimental technique.

Despite a rather lengthy treatment, neither the empirical nor the theoretical aspect has been exhaustively treated. There are many additional studies yet to be undertaken. Moreover our criticism of alternative outlooks did not lead to a satisfactorily elaboration of the relationship of phenomenal duration to "time". Nonetheless we have encountered important facts, suggested several principles, and proposed a theory to account for these principles.

PART II

FATIGUE AND DISORGANIZATION OF PERFORMANCE

I venture the guess that there is not a member of this association but has made fatigue the subject of direct, indirect, or projected investigation. Certainly few psychological subjects have so widely interested investigators in the allied sciences. Few seem to have at once such far-reaching bearings on psychological theory and the conduct of human affairs. Few present such a bewildering literature, with such an array of apparently mutually contradictory experimental results. None is more confused with an equal pressure for practical working rules.

Raymond Dodge
Presidential address
before the American
Psychological Association,
New York meeting,
December, 1916.

CHAPTER VI

THE PROBLEM OF FATIGUE

Introduction

The second part of this paper concerns the personal variable[1] fatigue (tiredness). Primarily, it is an investigation into the relation phenomenal duration and change, bear to fatigue. The assumption is that the phenomenal relationships established within Part I have something important to do with the emergence of fatigue within a situation. If this assumption should hold, then, because these phenomenal states are measurable, it could for the first time open the way to the possibility of expressing a genuinely personal experience in a strictly quantitative non-qualitative way. Moreover this measuration will have taken place, as we shall see by the definitions to follow, without having taken recourse at any point to specious redefinition of any variable, personal or phenomenal.

Incidental to the main problem, this part of the paper will also deal with the relation of fatigue to two overt behavior variables, the work performance variables of discrimination rapidity and accuracy. This excursion

1. An extended discussion of the matters of fact with which a scientific psychology must deal has been made by T. Nelson in an unpublished paper titled, "A Factual Basis for the Systematization of Scientific Psychology." This paper attempted to distinguish and provide useful and epistemalogically respectable foundations for "personal," "phenomenal," and "overt behavior" variables. Briefly, the "personal" responses are experiential events localized within the observer, the "phenomenal" responses experiential events that have reference to external non-organismic occurrences, usually to "objects" of some sort, and the "overt behavior" responses are non-experiential events, that can be observed in other organisms by a qualified observer.

was made for two reasons. First, it was made because the relation between fatigue and work behavior is highly uncertain if not unknown. Secondly, it was highly desirable, if not imperative, to use a common reference point for the subjects' report of fatigue. An obvious and useful point of reference is a task of some sort and this task may as well be of a kind that will yield useful data on another dimension of the human problem.

DEFINITION OF FATIGUE

Ordinarily providing a scientifically satisfactory definition of a personal variable, such as fatigue, would occasion difficulties at least as great as we found to be the case for duration. There can be no doubt that through the years the term has come to do too many services.[2]

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2. Orderly growth and permutation, the important and commonly accepted distinguishing trademarks of fruitful scientific concepts, are conspicuously absent here. S.H. Bartley and Eloise Chute within the classic of this area, Fatigue and Impairment in Man, have pointed this out. They say the following regarding the plethora of reference:

"In the history of experimental study of fatigue, several trends have been obvious. The first of these is toward a variety of diverse viewpoints. Much of this diversity has arisen from the variety of branches of science represented by the investigators. Fatigue, for the physiologist, was something pertaining to muscle and nerve activity. Fatigue, for the biochemist, also pertained to the tissues, but was studied in terms of chemistry. Fatigue, for the psychologist, had more varied interpretations, perhaps most commonly pertaining to performance, studied in terms of work output. Occasionally, in psychology, fatigue was seen as being somehow allied to the subjective. Fatigue for the physician, especially for the psychiatrist, was usually seen as subjective, although its basis was often sought in physiology. Thus instead of all branches of

Research published by Bartley and Chute greatly modifies the anticipated difficulty, however. This source, Fatigue and Impairment in Man,[3] constitutes an investigation into fatigue as a matter of fact and into fatigue as a theoretical tool, i.e. into fatigue as a concept. The end result has been the production of a clear-cut, sufficiently broad, provisional definition for the term. Hence, the criteria quoted below satisfy the present requirements of scientific psychology directly and these will be the distinctions that will serve us here.

Fatigue:

This is what Bartley and Chute say of the most important factual referent of fatigue:

> "Fatigue as an unpleasant experience has entered into the life of everyone. For the one who is tired, the feelings experienced are the fatigue.[4]

This is how they describe the larger organismic event characterized by this experience:

> "Fatigue is a part of the individual's stance with reference to activity, whether the activity is vigorous exertion, the assump-

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science actually studying component phases or aspects of a single phenomenon, many kinds of fatigue came to be assumed. In many instances these assumptions with such definitions as were made had little to do with each other. There was also a trend toward applying the term fatigue to all sorts of systems, and even to inanimate objects, such as metals." Bartley, S.H. and Chute, E.(New York: McGraw-Hill Book Co., 1947, p. 2)

3. S.H. Bartley and E. Chute, Fatigue and Impairment in Man (New York: McGraw Hill Book Co., 1947).

4. Ibid., p. 1

tion of an attitude toward a proposition, the maintenance of a posture, or merely the need for staying awake, etc. Fatigue involves aversion and a feeling of unwillingness and inadequacy for activity. This aversion, when analyzed, can be seen to arise out of personal conflict and to be an expression of frustration.[5]

Fatigue is personal. Fatigue pertains to the individual as a whole. Fatigue is consistent with the individual's ideals, goals, etc., and with his evaluation of himself. Conditions for fatigue are unique to the individual. The dynamics of fatigue cannot be adequately described in other than personal terms.[6]

Fatigue is an outcome of conflict. The organization of the individual is not so simple as to constitute singleness of desire or tendency. Conflicts are constantly developing, and at any one time many conflicts exist in an individual. Conflict cannot be avoided in active situations, and conflict thwarts action. Many conflicts find resulution in appropriate action, others are very poorly resolved, and still others fail to find resolution at all. Pervasive bodily discomfort is one of the most frequent outcomes. Following its onset the individual becomes increasingly certain of the appropriateness of changing his present behavior. When relief of bodily discomfort is prevented and action is thwarted, fatigue commonly develops.[7]

Fatigue is cumulative. Fatigue arises at a level of organization which must be dealt with in terms that reach beyond the immediate situation. Fatigue developed on one occasion is likely to be revived when a similar occasion arises.[8]

Fatigue's onset and recovery may be sudden. While impairment is a condition that is more or less gradually reached and recovered from, this is not always the case with fatigue. It is common knowledge that individuals do suddenly feel

6. Ibid.
7. Ibid.
8. Ibid.

> tired and quite as quickly experience release from fatigue. Fatigue can come and go nearly as rapidly as an individual is able to shift from one frame of mind to a different one.[9]
>
> Fatigue is never specific to a given body member. It, in other words, is never localized, but is general. Bodily sensations, such as feelings of discomfort, can, of course, be localized, but it is only the individual as such that can experience fatigue." [10]

It should be noticed here that "fatigue" and "tiredness" are not necessarily identities. This mistaken interpretation is habitually made. Bartley and Chute were not merely arguing about the use of a word, rather they were urging psychology to face an important and neglected matter of fact. The two terms can be separated in the following manner.[11]

Tiredness is the experienced component of the organismic event "fatigue". This experience is the manifestation and the nave of a peculiar organismic occurrence. Thus, one can say that there is no fatigue without tiredness. Fatigue, on the other hand, while it must include tiredness, includes as well the organic strains produced by the "disorganization" occurring with the central nervous system (what Bartley calls "stress" or "conflict of dominance", or sometimes "dual dominance"), the energy exchanges taking

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10. Ibid.
11. In all fairness, it must be said that Bartley and Chute did not make this distinction clear in Fatigue and Impairment in Man. Personal conversation with the senior author however, indicates to me that in the present, and in his case at least, some such discussion is desirable if not absolutely mandatory.

place at a receptor cell level between the organism and the external world, and finally, the specific or characteristic external situation itself accompanying the tiredness.

Other Variables:

In addition, Bartley and Chute distinguish between fatigue and impairment, work output, boredom, and monotony.

Regarding impairment and fatigue they say the following:

> "...........impairment will be used to refer to specific tissue conditions.
>
> Impairment is a physiological change in tissue which reduces its ability to participate in the larger aspects of organic functioning. Impairment is identifiable only through the methods of physiology and biochemistry. Reduction in the ability of the organism, as a whole to perform, is no criterion for the presence of impairment.
>
> Unlike fatigue, impairment is never directly experienced. The presence of impairment, like that of other physiological changes, cannot be deduced introspectively. It is well known that bodily functions may become diminished or distorted, and that even pain may arise, in the absence of tissue impairment. Despite this, it has been customary even among sophisticated individuals to deduce the presence of impairment from overt behavior or from bodily feelings. The bodily components that form a part of the experience of fatigue are no accurate sign of the presence of impairment."[12]

Regarding work output and fatigue they say this:

> "The term work output has been identified both with impairment and with fatigue. Although there is little confusion about the meaning of

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12. Bartley and Chute, op. cit., p. 48-49.

the term itself, many difficulties lie in the broad applications of the concept. Work output includes all overt activity that is measured either in the laboratory or in industry.

Work output is of immediate interest only in practical situations. In studies of productivity, external conditions may be systematically varied and the changes in work output noted. However, inferences about the organism made from studies of this sort are not justified. In dealing with fatigue and impairment, we are attempting to come to a knowledge of the individual organism. Since work output can give little clue to what is happening within the organism, it is unfortunate that productivity has been used as a measure of fatigue and impairment. When the attempt is made to relate organismic behavior to external conditions, it must be recognized that the overt response of the moment may not be related to the physical world in any simple way.[13]

Regarding boredom and fatigue this is said:

"Fatigue is not to be confused with boredom. Frequently when fatigue is used synonymously with impairment, the experiential aspect of the individual's response to certain situations is termed "boredom". Introspection reveals that a bored individual attributes his state to environmental events, whereas a fatigued individual lays the blame for his condition on himself. It is felt that merely escaping the situation will alleviate boredom and that it is therefore more transient than fatigue. It might be said that both boredom and fatigue are stances taken by the individual toward situations confronted. Fatigue, however, is by far the broader term. While boredom may form a part of the fatigue picture, the reverse is not possible."[14]

They say of monotony:

"The term "monotony" suggests sustained and unpleasant sameness. Both intricate and simpler tasks can become tedious, but is is usually simple, repetitious tasks that become monotonous.

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13. Ibid., p. 49
14. Ibid., p. 55.

> Monotony is a general characteristic that may be imputed to the work at hand. It is a term used to label the individual's perception of his surroundings, and although often spoken of as belonging to the situation, can imply no fixed relation between situation and experience. Work is characterized as monotonous by an individual, and that which is monotonous for one may be quite interesting for another. Any sort of work at one time or another may become unpleasant, tedious or monotonous. Our purpose here is not to further identify monotony, but to analyze it in order to see how it contributes to fatigue.
>
> Work is judged tedious or monotonous when it loses its importance to the worker."[15]

Operational definition of fatigue:

A general characterization of fatigue has been given. It is now necessary to describe possible experimental equivalents of the term.

In the past, experimenters have relied upon either periodic introspective reports during a task performance or periodic reports of degrees of feeling tone as expressed on a quantitative scale of some sort.[16] Neither of these methods is very satisfactory from the present writer's viewpoint, for many reasons.

The introspective method suffers in three ways. First, the assumption seems to be that fatigue is always a condition that is gradually reached and from which one slowly

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15. Ibid., p. 340.
16. A.B. Bills, "Studying Motor Functions and Efficiency," Methods of Psychology, ed. by T.G. Andrews (New York: John Wiley and Sons, Inc., 1948), pp. 459-467.

recovers. This confusion is natural if one thinks of fatigue as a manifestation of impairment rather than disorganization. Nonetheless, the fact is that the onset and recovery of fatigue is very often sudden. Thus, methodological artifacts are introduced by the collection of periodic introspective reports. Fatigue can occur and wane without being reported, and, once reported, may not persist simply because the task is continued. Second, the procedure of periodic report also demands that some assumption be made regarding the effect of these "laboratory interruptions" upon the continuous work. We have already seen that abruptions or change have an important effect upon experienced duration and what reason is there to suspect that these same factors will have no effect upon fatigue? Then, there is the ancient semantic problem to consider. Just what fact does the observer refer to when he is forced to report and says "tired"; "a little tired"; "very tired"; etc.? There is, of course, no possibility of knowing whether he means the same thing each time he uses a given description, particularly as the task continues. A shifting of reference is one of the acknowledged dangers of unstandardized introspections.

The use of rating scales is widespread and lessens the semantic danger referred to above. Poffenberger [17]

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17. A.T. Poffenberger, "Effect of Continuous Work on Output and Feelings," J. Appl. Psychol., XI (1928), pp. 459-497.

and Thorndike [18] used "feeling tone" scales to express fatigue in their studies. No doubt a 5 or 7 point graphic scale, ranging from "the greatest aversion to continuing work I have ever felt", to "the least aversion to continuing work I have ever felt," presents less ambiguity and greater reliability than uncontrolled report. Nonetheless there are serious problems to be confronted here too by the experimenter who decides to use this method. The experimenter must take into account errors in rating. Eventually the ratings must be translated into a common distribution in order to make the results comparable from one subject to another. Fairly, large numbers of subjects must be used. The problem of application of the normal sistribution curve to fatigue descriptions must also be resolved. When and if these problems are satisfactorily met, we still have the two introspective problems before us. When shall the reports be obtained during the work session so as not to serve as a "distraction" and so as not to "interrupt" the "continuity" of the task? What assumptions about fatigue are necessary before one can make use of these scales?

In the present case the attempt will be to limit the description of fatigue to a single simple, clearly understood fact. The individual will only have to rate his personal stance once and this will be in a way universally

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18. G.L. Thorndike, "Curve of Work and Satisfyingness," J. Appl. Psychol., 1 (1917), pp. 265-267.

understood. The subject will be required to indicate when he becomes too tired to continue. Under this plan the experiment need not be interrupted for reports. There will be no attempt to measure fatigue directly by means of any rating device. We shall see later that this decision does not exclude fatigue from the category of measurable phenomena however. Through the years, the physical sciences have succeeded quite well using indirect quantitation.

Operationally, then, fatigue will be considered to be the compliance of the subject in an experimental setting to the following instructions, "You are to work at this task until, by reason of tiredness, you can not go on."

We will now turn to review previous work related to the task outlined in the Introduction of Part II.

CHAPTER VII

CONTEMPORARY WORK ON THE PROBLEM OF FATIGUE

Prior Experimental Work.

The lack of agreement concerning the empirical referent of fatigue severely reduces the literature potentially available for review. It was a major contribution of Bartley and Chute[1] to show that most of the publications, purporting to deal with fatigue, have nothing at all detectable to do with tiredness. On the basis of a later review by Bartley [2] in 1956, and on the basis of a personal independent review of the literature written after 1947, the year *Fatigue and Impairment in Man* appeared, and in spite of a noticeable improvement in the situation, this must still be said. The area was, and is still hamstrung, by a specious and misguided operationalism that precludes the bulk of work from having any relevance to fatigue as a matter of fact.

We will assess the literature available in two ways. First we will consider the phenomenal correlates of fatigue. Secondly, we will consider motor discrimination and reaction time and fatigue.

Phenomenal variables correlated with fatigue:

There is no experimental work reported that relates phenomenal duration, change, or movement to fatigue as a

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1. Bartley and Chute, *op. cit.*
2. S.H. Bartley, "Fatigue and Inefficiency," *Physiol. Rev.*, XXXVII (1957), pp. 301-324.

personal variable. Moreover, the researches relating any sort of phenomenal variable to fatigue are disappointingly limited. What there is will be briefly summarized.

The phenomenal variable, most frequently used, has been that of flicker fusion. Typically, workers have attempted to show that the flash rate necessary to produce an experience of steady illumination will undergo some continuous and characteristic modification, which will permit the fusion level to be used as an index of the individual's self appraisal of his ability to continue in the performance of a task, or as an index of the task performance itself. Bartley and Chute reviewed the CFF work reported prior to 1946, especially the work of Lee and of Simonson, Enger, and Blankenstein,[3] and were not able to discover any such system of relationships. Neither did the later experimental reports of Bujas, Petz, and Krhovic[4] show CFF to be reliably related to fatigue.

Researches that have related fatigue to a more general phenomenal situation, rather than to some isolated, simple perceptual discrimination have been somewhat more successful. In this connection, Gross and Bartley[5] report the results of interviews with a group of six housewives who

3. Bartley and Chute, _op. cit._, pp. 161-162.
4. Z. Bujas, B. Petz, and A. Krhovic, "Can the Critical Flicker Frequency of Fusion of Interrupted Electrical Stimulation of the Eye Serve as a Test of Fatigue," _Arh. Hig. Rada._, 111(1952), pp. 428-438.
5. I.H. Gross and S.H. Bartley, "Fatigue in Housecare," _J. Appl. Psychol._, XXXV(1951), pp. 205-207.

complained that "great fatigue" was attendant with their household work. Their interviews showed that these women were characteristically "bewildered" by household clutter. In another study, Littlejohn[6] studied occular tiredness associated with typewriting. He found a relation to exist between certain selected degrees of angle of typewriting copy and ocular tiredness. Despite this, 50 of the 64 subjects did not express a consistent preference for any one of the three "non-flat copy" positions. Neither did the data show any clear superiority in terms of fewer errors of angle over another.

Motor response latency, accuracy of discrimination, and fatigue.

We stated in the Introduction to Part 2 that, in addition to the primary phenomenal variables, certain overt behavior variables are to be related to the personal variable fatigue. The variables selected have been those of reaction time and discrimination accuracy.

The literature dealing with reaction time is copious and has been periodically reviewed. In all, there are well above 200 separate article references, with many of the older references encompassing several studies, as well as

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6. V.T. Littlejohn, "Relationship Between Selected Degrees of Angle of Typewriting Copy and Ocular Fatigue in Typewriting," Abstracts of Doctoral Dissertations, 1948, University of Pittsburg, pp. 290-301.

numerous whole chapters in experimental handbooks and manuals.[7]

Nevertheless, the literature available for review in our case is surprisingly limited. Most of the early literature seems to be concerned with theoretical introspective problems, problems of mental structure and function, while more recent work attempts primarily relate to work productivity, aging, nerve physiology and alterations of response time. Some of these studies will be referred to later in another connection. For the present, however, several comparatively early studies are all that merit attention.

The work of Wells, Kelley and Murphy[8] is most notable in this respect, although poorly reported and probably poorly controlled. Their procedure was simple. A "non-exhaus-

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7. The best of the general reviews of reaction time are provided by: H.M. Johnson, "Reaction time measurements," Psychol. Bull. XX(1923), pp. 562-589; R.H. Woodworth, Experimental Psychology (New York: Henry Holt and Co., 1938); W.H. Teichner, "Recent Studies of Simple Reaction Time," Psychol. Bull., LI(1954), pp. 128-149.
   An excellent review of the early history of reaction time is provided by V.A.C. Henmon in "The Psychological Researches of James McKeen Cattell," Arch. Psychol., IV,No.4, pp. 1-34.
   Two other specialized reviews have also been made. They are: J.L. Fenau, S.C. Finan and L.D. Hartson, A Review of Representative Conditions Related to Aircraft Flight. Dayton,Ohio, U.S. Air Material Command, Wright-Patterson Air Force Base, IV(1949), U.S.A.F. Tech. Rep. No. 5830,; and G. Forlano, J.E. Barmark, and J.D. Coakley, "The Effect of Ambient and Body Temperature upon Reaction Time," Special Services Center Report No. 151-1-13, 1948.

8. F.L. Wells, C.M. Kelley, and G. Murphy, "Effects Simulating Fatigue in Simple Reactions," J. Exp. Psychol., IV(1921), pp. 57-62.

ting" reaction task was used. The subjects were required to press a telegraph key when an expected signal, either visual or auditory, appeared. The experiment was divided into halves, both halves requiring the subjects to make 54 reactions to light and the same number to sound, a total of 108 responses per half. The signals were not given rapidly since they report that "about 40 minutes" was required for the total experiment, including a mid-point "pause of perhaps 90 seconds."..This means a signal on the average, every 11 seconds. The simple reaction times recorded from 13 subjects and the 2 experimenters (K. and W.) during the first half of the experiment, were compared to the reaction times recorded during the second half. Their resume of the response time data appears in tables 8 and 9.[9]

Table 8

PER CENT. WHICH THE QUARTILE RATIOS OF THE FIRST HALF ARE QUARTILE RATIOS OF THE ENTIRE EXPERIMENT.

Subjects	A-Group	K	W
Av.	49.9	50.2	49.8
Mv.	1.2	.7	.4

Table 9

PER CENT. WHICH THE REACTION TIME SCORE IN THE SECOND HALF OF THE EXPERIMENT IS OF THE SCORE IN THE FIRST HALF

Subjects	A-group (13 persons)	K	W
Av.	104.9	105.1	106.3
Mv.	4.9	4.8	3.5

These response time data were in turn related to introspective reports given by one subject (w) and to general observations of the overt behavior of the remainder. The experimenter, as subject "W" reported that he experienced increasing "logeyness" and found it "the most ennuyant of experiments"[10]. The overt behavior observations, gathered showed "increasing sommolency, yawning or stretching, etc." This led the experimenters to conclude the following regarding the latter part of the experiment:

> ---"In sum, the present experimental conditions are such as to make the reaction times in the second half of a forty-minute experiment, average 105 per cent of those in the first half. These conditions, with their moderate work and ample rests pretty well exclude exhaustion in the lower nervous arcs and allow a monotony effect to appear in relatively pure form."[11]

Cattell's early work (1885) at Leipzig is also of interest. Cattell made two rather extended investigations,

9. Charts taken from Ibid., p. 138
10. Ibid., p. 139.
11. Ibid., p. 141

using himself and another student (B) as subjects. The first study used simple reactions to lights and sounds and a discriminative reaction, reporting the names of letters. The first experiment was conducted as follows: Three task lengths were used for each type signal. One series was comprised of 16 units, another of 26 units, and another of 200 units. Each series of each length was repeated 30 times and averages taken. The published results generally support Cattell's conclusion that the response latencies increased with time. His tables show that the first reactions of each series were the shortest, although these differences were "not great." Percentage-wise the final reactions in Cattell's light leries average 122 per cent of his initial reaction time, although B's show no appreciable increase. Neither show any differences in the sound series. In the discriminative reactions both show relatively large reaction time increases. Cattell's are 113 per cent and B's 131 per cent of those recorded in the initial series.[12]

Cattell in the same article also reports the results of an investigation into the effects of long periods of work upon reaction times. The tasks consisted of signaling when a light, letter, or sound appeared and of naming a letter, word, and color. Excluding short interruptions for meals

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12. R.B. Cattell, "The influence of Attention, Fatigue, and Practice on the Duration of Cerebral Operations," Mind, XI (1886), pp. 534-538.

each subject made 1950 reactions. Cattell began at 7:30 A.M. and stopped at 1:30 A.M., while B began at 7:30 A.M. and stopped at 11:00 A.M. No introspective reports were published but the tables show a slight increase in reaction time for Cattell on each task late in the day and a general but slight increase for B.[13] Of greater interest is the fact that when single repeat series were fun at 8:30 A.M. and 8:30 P.M. the next day and the day after, the response latencies generally remained well above the previous starting and stopping limits. In one type of reaction B's time was still about 117 per cent above the beginning point. Cattell says regarding these results that:

> "The brain substance concerned in the simple reaction seems to have been so far exhausted that his reaction time remained abnormally long for two days."[14]

Finally, Woodrow[15] in a 1914 monograph, The Measurement of Attention, contains data related to our problem. The research referred to did not directly concern fatigue and reaction time but rather concerned the relation of simple reaction time to the length and character of the preparatory period. Reaction times were studied via the following two procedures. Under plan "A" response time measurements were made to 30 visual signals with a 2 second preparatory period. This activity was followed by a brief rest. The rest was

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13. For some reason no reports were published of reaction times after 8:50 P.M.
14. Cattell, op. cit., p. 538.
15. H. Woodrow, "The Measurement of Attention," Psychol. Rev., V (1914), 158 pp.

was followed by a sequence of 30 additional visual signals with preparatory intervals varying from 4 to 20 seconds. Under plan "B" the opposite order was used (the irregular preparatory periods preceded the rest period). Each of these experimental sequences, including the rests, occupied an hour. A total of 72 separate sequences were run on 2 practiced subjects (36 per subject). This made available 4,320 responses for averaging. This countervalanced design allows one to compare the reaction times under a given type of preparatory interval both before and after a period of performance and rest. The averages of these 2 subjects are presented in tables 10 and 11:[15]

Table 10

AVERAGE REACTION TIME AND MEAN VARIATION IN THOUSANDS OF A SECOND WHEN THE SUBJECTS WERE FRESH.

	2 sec. Preparation		Irregular Preparation	
	Mean	Mean V.	Mean	Mean V.
Subject 1	205	19	309	31
Subject 2	193	20	281	27

Table 11

AVERAGE REACTION TIME AND MEAN VARIATION IN THOUSANDS OF A SECOND WHEN THE SUBJECTS HAD ALREADY PERFORMED.

	2 sec. Preparation		Irregular Preparation	
	Mean	Mean V.	Mean	Mean V.
Subject 1	227	21	325	37
Subject 2	205	22	286	30

15. Both tables prepared from Woodrow's data, Table XVII, *Ibid.*, p. 130.

If one compares the data from the "fresh" to "already performed" condition, a small increase in both reaction time and mean variability is readily apparent for both subjects (205 to 227, 19 to 21, 309 to 325, etc.). Other data Woodrow presents shows, however, as did Cattell's, that a regular increase did not occur when an auditory rather than a visual reaction signal was used.

We will now turn to a more detailed statement of the present problem.[16]

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16. The relation of general work productivity to fatigue has been the object of more direct and intensive study. An investigation by C.T. Yaokum in 1909 includes 7 pages of introspective reports given by subjects after short intervals of work.("An Experimental Study of Fatigue," Psychol. Rev., XI, No. 3(1909)). T. Arai's work in 1912 is generally considered as a classic in this area("Mental Fatigue," Teacher's College Columbia, Contributions to Education, LIV(1912),pp. 1-115). E.L. Thorndyke in 1917 published a short paper giving the results of a direct investigation into the problem,("Curve of Work and Satisfyingness," J. Appl. Psychol., 1(1917),pp. 265-267). B. Muscio did the same type of problem in 1921, ("Feelingtone in Industry," Brit. J. Psychol.,XII(1921),pp. 150-162). This was followed by a similar study by A.J. Poffenberger in 1928, ("Effect of Continuous Work on Output and Feelings," J. Appl. Psychol,(1928), pp. 459-467). A short general review of some of this earlier work is provided by A. Bills in 1934, (General Experimental Psychology.(New York: Longman, Green, and Co., 1934).

More recently, work on this topic is reported in the following articles: Z.L. Huxtable, M.H. White and M.A. McCartor, "A re-performance and Re-interpretation of the Arai Experiment in Mental Fatigue with Three Subjects," Psychol. Monogr., XXII (1946), pp. 181-192; D.B. Tyler,"The Effect of Amphetamine Sulfate and Some Barbituates on the Fatigue Produced by Long Wakefulness," Amer. Jour. Physiol., CL(1947), pp. 253-260; M.E. Bitterman,"Transfer of Decrement in Ocular Tasks," Amer. J. Psychol, LIX(1946), pp. 422-438; J.W. Griffith, W.A. Kerr, T.B. Mayo, and J.R. Topal, "Changes in Subjective Fatigue and Readiness for Work During the Light Hour Shift," J. Appl. Psychol., XXXIV(1934),pp. 163-166; T.M. Nelson, and S.H. Bartley, "Feelings of Fatigue, Rest, and Boredom During Work Days of Varying Lengths, (unpublished).

CHAPTER VIII

EXPERIMENTATION

Hypothesis 1.

Since the time of VonEhrenfels, Cornelius, and Lipps, psychologists have been aware of the fact that behavior always occurs within a context. Gestalt Psychology gave a formal place within theory to this fundamental fact. Early in the century, Köhler wrote that:[1]

> "....a description of what is given in sensation must remain incomplete, and untrue to the reality, so long as the familiar variables of our sensory psychology are deemed to be adequate for the purpose; that, moreover, in the customary descriptions, a large and important part of the properties of perception is neglected. This actually retires to the background in the extreme instances achieved by isolation; but from the point of view of the psychology of perception, is often more important than the current moments of sensation, as soon as, in addition to the peripheral conditions, the remaining factors also exercise their influence; namely, in the psychical correlate of manifolds of stimuli, especially in the perception of things, as in ordinary life."

Indeed, everyone in psychology today, laboratory behavior to the side, gives service to the rule that every figure is "ground determined" and every ground "figure determined". Consequently, fatigue must have something to do with the context in which it occurs.

This thesis raises a very grave methodological question for the experimentalist, however. It is obvious that if

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1. W. Köhler, "Über unbemerkte Empfindungen und Urteilstäusechungen," Zeitschrift für Psychologie, LXVI(1913), pp. 79-80 quoted by B. Peterman, the Gestalt Theory and the Problem of Configuration (London: Routledge and Kegan Paul, Ltd., 1932).

this principle is sound, then it is a reasonable procedure to consider the ambient conditions first and the parts of the context, specific experiences such as tiredness or behaviors such as reaction time, secondly. Hence, the experimentalist, here as elsewhere, must be prepared to answer at least two questions on the matter of fact, i.e. the laboratory, level. The first question asks, "What is the important context?", and the second, "How can the ambient conditions be characterized?"

In the research to be proposed, it seems possible to answer both questions unequivocally because of the work reported in part one. In part one, the reader will recall that phenomenal duration, change and movement were given definitions that remained true to everyday fact, but that, at the same time, provided operational equivalents which permitted the facts to be observed experimentally--to be observed in a way consistent with scientific necessities. Once these facts were within the scope of laboratory treatment, controlled experimentation gave to them a more full, precise and consistent empirical characterization. This prior characterization, so far as it has been sufficiently complete and successful, will provide ambient variables with the unique advantages of being precise, legitimately defined, and organism centered.

Hence, in the present study, phenomenal duration, change and movement conditions are to be used as the ambient conditions for the performance of a task leading to fatigue.

In using these variables, it is assumed that the overall system of change, movement, and duration, which always exist in some form as a background for activity, are contributors to the individual's change in stance toward the activity. The approach of the present study implies that fatigue will develop more rapidly under some ambient conditions than others. <u>Specifically, the first hypothesis to be tested is that fatigue on a given task will develop as a function of the ambient conditions of duration.</u>

Hypothesis 2.

One of the oldest and most puzzling problems facing psychology has been that of the relationship between experience and overt actions.

Within the area of fatigue and work, the experimental outcomes have been especially disappointing. Previous experimentation has been able to show only a very poor relationship between energy expenditure, the amount of work done, and the emergence of fatigue. Research oriented towards studying the effect of fatigue on work output has been equally unsuccessful, although in neither case does anyone seem prepared to deny that a relationship exists. Ordinary observation insists that some tasks produce fatigue more rapidly than others and that a condition of fatigue can not long exist without producing changes in one's performance of a task.

Specifically, we will test the hypothesis that the emergence of fatigue will detract from the adequacy of performance of a reaction time task.

The Experimental Investigation

Purpose: The experiment was designed to provide an empirical test for hypotheses one and two.

In order to test hypothesis one, two ambient phenomenal change conditions leading to "long" phenomenal durations will be pitted against a phenomenal change condition producing "short" phenomenal durations. The hypothesis will be considered to be confirmed if the two conditions leading to a "long" duration both result in the production of fatigue, either more rapidly or more slowly than the single "short" duration phenomenal change condition.

In order to test hypothesis two, a measure of simple reaction time will be made before and after the onset of tiredness. The hypothesis will be considered to be confirmed if the simple reaction time measures occurring before fatigue are both more rapid and less variable than those occurring after the onset of fatigue.

Subjects: A total of three subjects were used. Subject D was a 20 year old female. Subjects B and R were males, 27 and 19 years of age respectively. All three subjects were college students and naive to the purpose of the experiment, although subjects D and B had extensive experience comparing durations in the experiments of part one. The subjects were paid for their services since the experiments were somewhat unpleasant and extended in length.

Apparatus: The apparatus described in experiments 3 and 9 of part one were used to produce the ambient conditions for this task. The provision of a fatiguing task and the measurement of reaction time necessitated several additions to be made to the equipment. The additions will now be described.

Wide lines about 6 inches in length were inked on the edge of the screen at "12 o'clock", "3 o'clock", "6 o'clock", and "9 o'clock" positions. These lines allowed the subject to identify the position of colored targets which were flashed on the screen as "hours". In figure 48 the light sources producing the colored targets are pictured. The right light source is a navy spot lamp equipped with a blue filter and 20 watt special purpose bulb. This source was fixed in position, and went on and off by manual operation of a knife switch. When the switch operating this lamp was closed,a discernable"M"-shaped target, blue in color, fell on the center of the screen. A stopwatch was used to measure the clock-length of this exposure. The left source pictured in figure 48 is a simple flashlight placed in a holder fastened to a platform which in turn is fastened to a ball joint. The socket of this light housed a five-cell bulb which was connected to five large dry cells. At the distance used, the light made approximately a 3" spot of ill-defined contour. The color of the targets could be changed. The colors were changed by putting filters in front of the lens. Three colors, blue-green, red, and amber were used. Because of the ball joint arrangement the experimenter could project the target anywhere on the screen. The light was actually aimed only at the extreme edges of the screen, however, and occurred only at the 12 hour positions of the clock. The positioning of this source was accomplished by the track device pictured to the rear of the platform. The left target light was shut off and on by a semi-automatic device pictured in figure 49. The device was made up of two micro-switches, a 4 rpm Telechron motor and a knife switch. With the knife switch in closed position, the motor shaft and attached arm made one revolution every 25 sec. A cord attached to the revolving arm extended to the micro-switch trips. During a fraction of the 25 sec. intervals, the cord would become taut enough to close both switches. The micro-switch which regulated the left target light was closed 3.60 sec. each revolution and, hence, each of the "12 hour" targets were exposed for 3.60 sec. A Standard Clock measuring clock length to one-hundredth of a second was also included in the circuit completed by this micro-switch. This clock was wired to stop when the signal light was on and run when the signal light was off. This arrangement permitted the experimenter to measure accurately the time between target presentations. The second micro-switch pictured started a second Standard Clock. The second Standard Clock was wired to go on 1.80 sec. before the left target light and stay open 1.80 sec. after the target light went out. Hence, it was open for 7.20 sec. in all. This arrangement was made so as to allow the experimenter to record "anticipatory" reactions and to measure reactions of very great latency, i.e. responses occurring after the light had gone out. It also served as an alerting device for the subject since the microswitches made distinct on and off clicks.[2] Two telegraph keys, equipped with microswitches for fast action, were wired into the second timing clock circuit. One key was mounted on the observer's chair as shown in figure 47. The other key was mounted on the table in front of an experimenter. (Figure 47 also). Both keys were in the closed position normally. Pressing either of the keys stopped the timing clock. Hence the subject could respond to the target by pressing his key and the

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2. This accounts for the very short and sometimes negative reaction time values to be reported (see figures 50 through 72).

experimenter could "hold" the clock until his reading was made by pressing the other key.

Several sets of random numbers, data sheets, a thermometer, a wet bulb device to measure relative humidity, and a household electric clock completed the additions to the equipment.

Method: Three experimental conditions were used. The only distinguishing feature between the three conditions was the ambient phenomenal change rate featured. The ambient change variations used to distinguish the experimental conditions were those known to produce definite effects upon phenomenal duration. In condition one, a phenomenal change set at rate 2 (experiment 1, part 1), occurred on the screen. This ambient change is the change found to be most effective in producing "short" durations (experiment 8, part 1). In condition two, a phenomenal movement rate was set at 15 (experiment 2, part 1) initially and decreased two points every 12½ minutes. This decrease was very gradual and hence phenomenal changes were periodically introduced into the continuity, (experiment 18, part 1). In condition three, the ambient phenomenal change rate was set at phenomenal change rate 12 (experiment 1, part 1). The effects of this latter ambient condition upon duration was investigated in part 1 (experiment 8). Conditions two and three provided change conditions

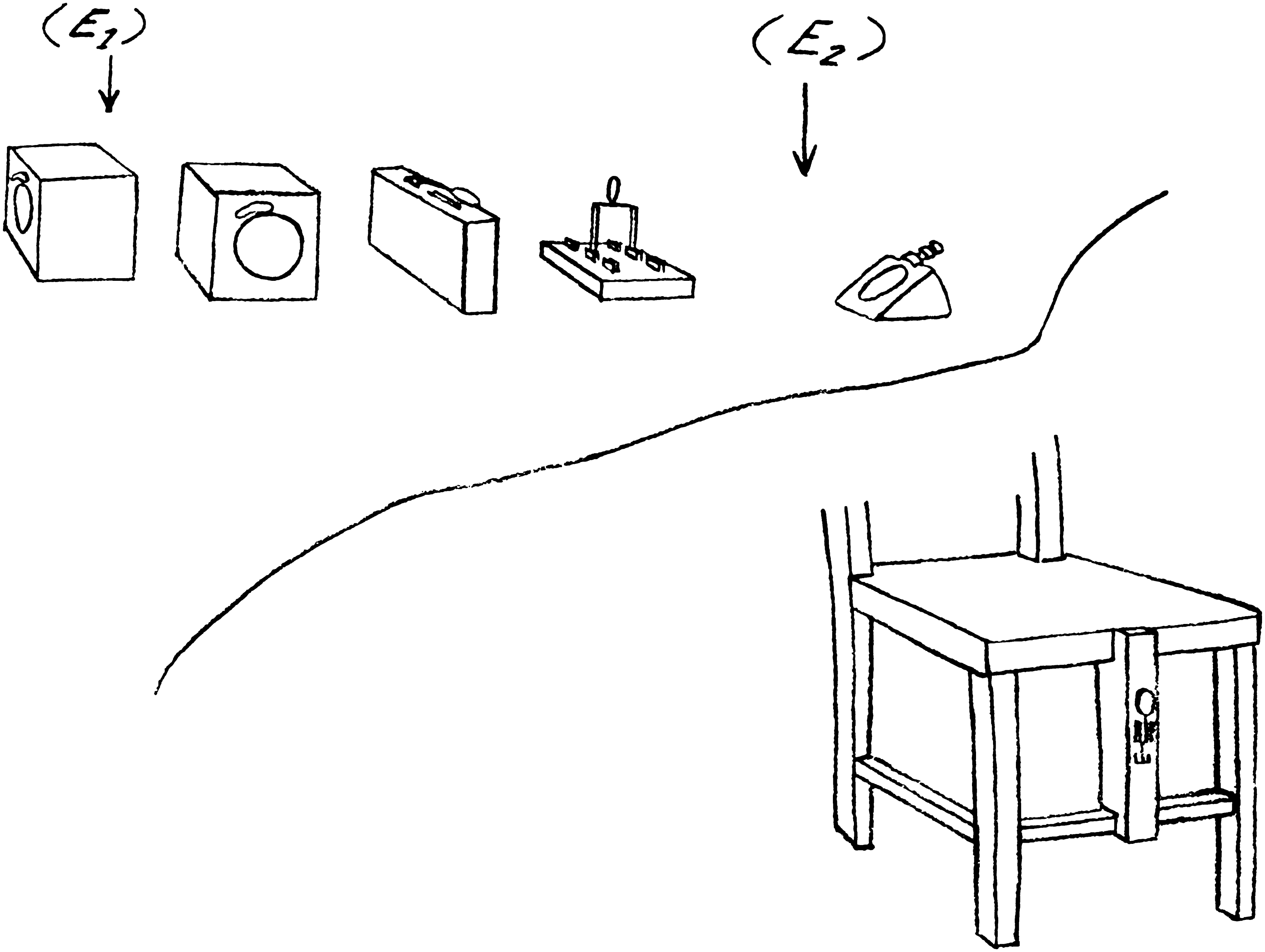

Figure 47. Additions to the experimental equipment previously pictured: The time clocks and telegraph keys.

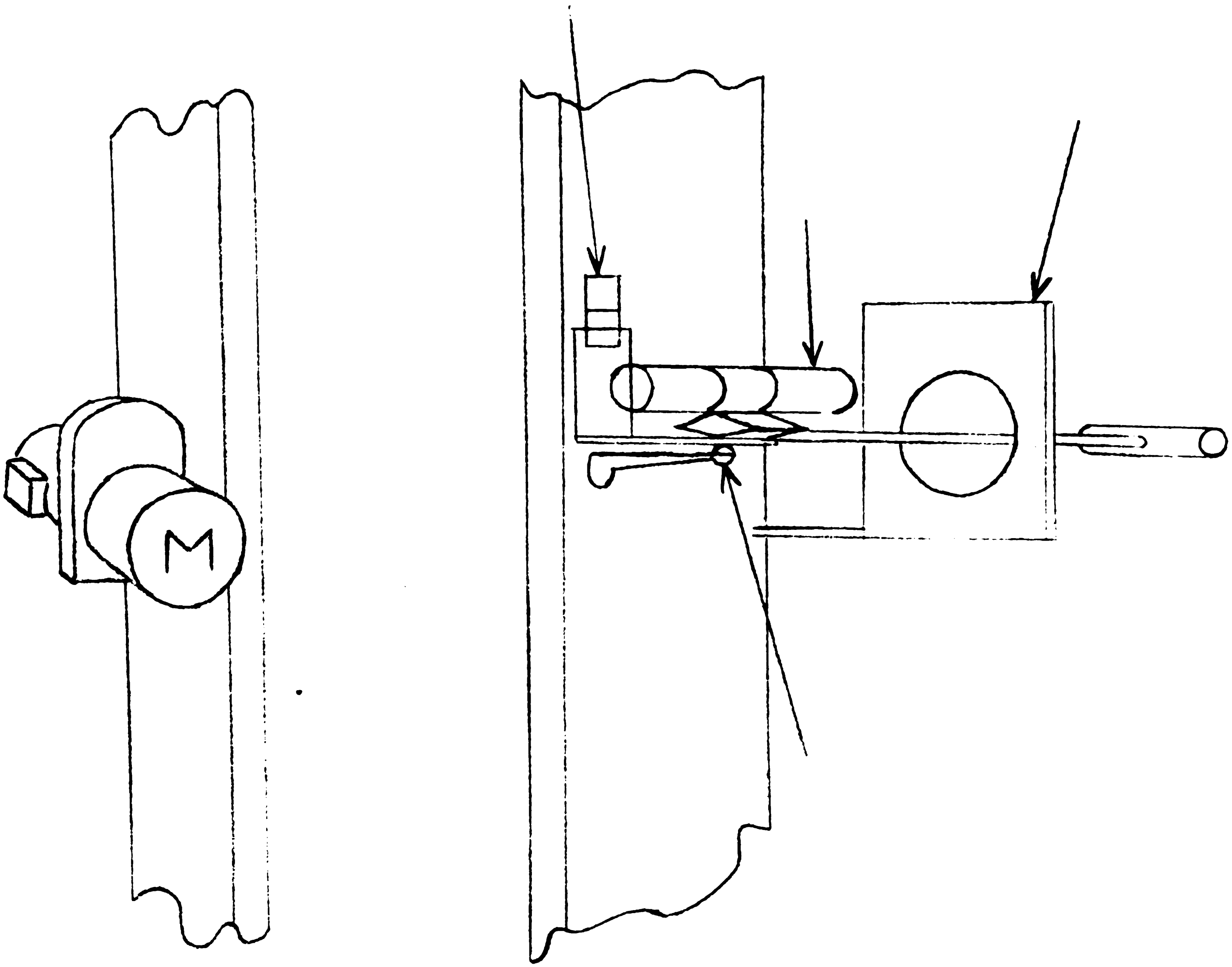

Figure 48. Additions to the experimental equipment previously pictured: The target producing devices.

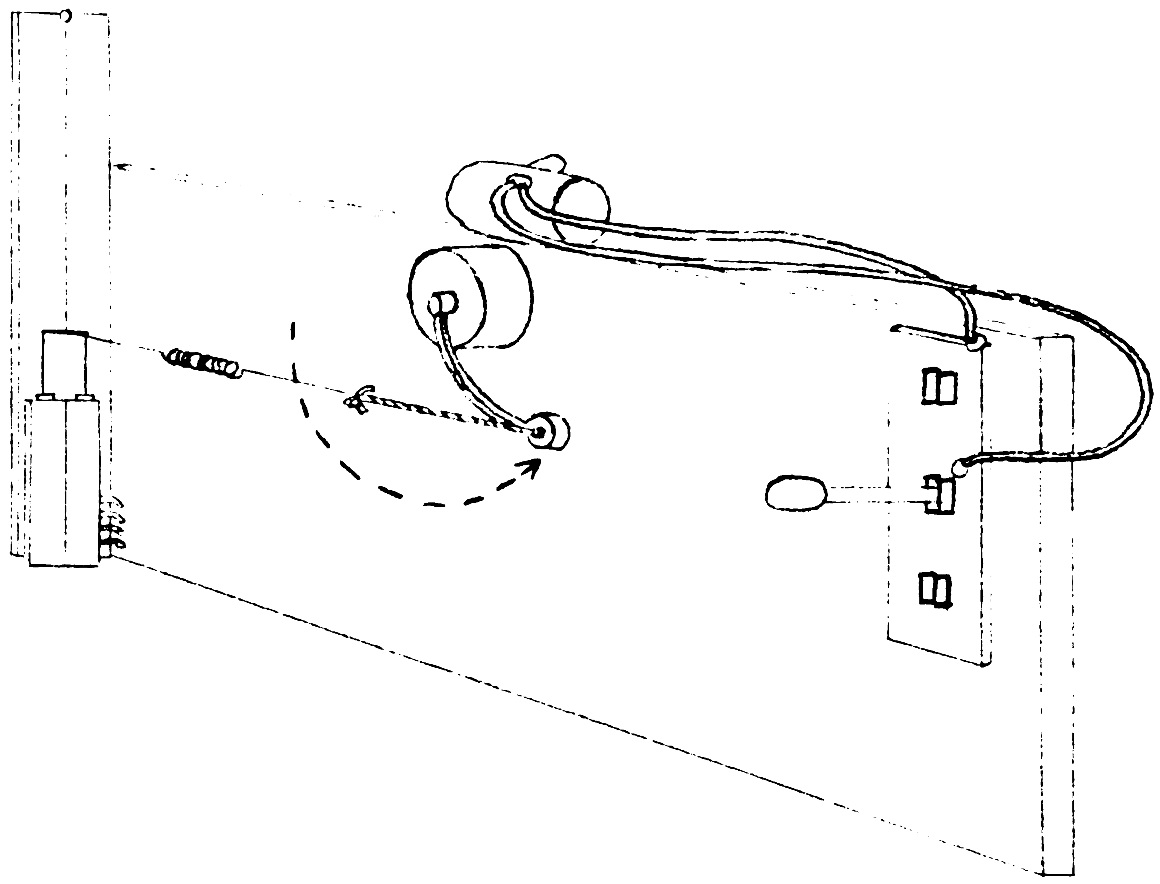

Figure 49. Additions to the experimental equipment previously pictured: The target timer.

effective in producing "long" durations. It is not possible to make a sharply detailed description of the relationships between the three experimental conditions because, as it was pointed out in chapter 6 of part one, the graphs represent frequency distributions of responses made under different conditions,[3] and because phenomenal scaling procedures were not used for the measurement of phenomenal duration.

The original plan required each subject to serve on 9 trials. The 9 trials were to equally represent the three ambient phenomenal change conditions, each condition being repeated three times per subject. The 9th trial in each case was to be extended well past the point of fatigue. The original plan featured a counter-balanced design with the experimental conditions following a prescribed pattern for each subject. As it worked out, however, an extra trial was needed for each subject.[4] The revised plan necessitated 10 trials per subject.

The new plan required 3 repetitions of two experimental conditions and 4 repetitions of the third condition. The final orders were as follows: for subject D, the pattern

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3. Figure 20 is based on a standard interval set at phenomenal change rate 12, Figure 21 is based on a standard interval phenomenal change rate of 2. Figure 22 is based on a standard interval phenomenal movement rate of 12.

4. Subjects B and C were unable to comply with the directions once each. These trials each had to be rerun. Subject A was run 10 times because the pre-fatigue part of the ninth trial proved to be so long that it did not allow the experimenter to include the "post fatigue" condition within it.

was 3,1,2 - 2, 1, 3 - 2, 1, 3 - 2; for Subject B, the pattern was 1, 3, 2 - 3, 2, 1 - 2, 3, 2 - 1; and for Subject R, the order was 2, 3, 1 - 1, 3, 2 - 3, 1, 2 - 3.

On each of the 10 trials the three subjects performed on two tasks. From the subjects' point of view, however, there was only a single task since the directions stipulated that when any visual signal appeared on the changing screen the subject was to (a) push the signal key as quickly as possible and then (b), to report on color and position of the target. These two tasks were different from the experimenter's point of view because they yielded different measures of reaction time. Task 1 was provided by the left target source previously described. (Figure 48). Using this source an experimenter flashed targets on the screen allowing: (a) the clock time between presentations to vary randomly from 10 to 100 sec., (b) the color of the targets to vary randomly from blue-green to red to yellow, (c) the target positions to vary randomly over the twelve "clock" hours. Task 1 yielded a measure of motor reaction time, the time required to push the signal key and hence break the circuit. This response was measured to the hundredth of a second. Task 2 was produced by the right target source previously described (Figure 48). Using this source, an experimenter flashed the blue "M" on the center of the screen at irregular intervals, ranging from 2 to 15 minutes during the pre-fatigue part of the experiment, and at intervals ranging from 2 to 7 minutes apart during the post-fatigue condition. This target remained on the screen until the subject gave the desired verbal response. Task 2 yielded a measure of verbal reaction time, the time required to report the color and position of the target on the screen. This response was measured to the twenty-fifth of a second.

Records of qualitative responses were also kept. First, records were kept of spontaneous personal and task evaluations occurring during the pre-fatigue part of the experimental trial. The subjects' shift in attitude toward the task, changes in feeling tone, experience of strain, discomfort, nervousness, tension, etc., were recorded immediately as they occurred during the experiment. Secondly, records were kept of the answers given in a post-experimental question period. During this period, the subjects were questioned primarily as to precisely why they felt that they could "not go on," as to what other, if any, experiences they had besides tiredness, and as to the course of development of the fatigue. The subjects were also asked upon this occasion to make a general evaluation of their task performance, to estimate the number of minutes they had served as subjects, and to elaborate upon the spontaneous reports given during the experiment.

Records were kept of the ambient relative humidity and temperature, since it was necessary to conduct the experiment during a warm time of year in a building with insufficient ventilation.

Procedure: The subjects were seated in the viewing position and given the following instructions each time they served:

"The screen is now dark. When the screen becomes lighted, that will be the signal that the trial has begun. Past this point we will not converse with one another under any circumstances. You will work by yourself as though no one is present. Since we cannot interrupt the task for any reason, it is important that you allow me to answer any questions you may have now and important that you make certain that you are not thirsty, that you have your cigarettes and matches and so on, before we proceed. (Pause).

This is what you are to do. You are to attend to the lighted screen which will appear to change kaleidoscopically. Eventually a signal light will suddenly come on. When this happens, you are to press the signal key on the chair as rapidly as you are able. After you have done this, immediately report the color and position of the light you saw. The signal lights will appear both on the upper edge of the screen and on the very center. Those lights appearing around the edge of the screen will either be blue-green, red, or yellow, and will be flashed at one of the "clock-hours". You will notice that the screen has been marked with a "12 o'clock", a "3 o'clock", a "6 o'clock," and a "9 o'clock" mark to make your task of reporting easier. The signal light falling in the center of the screen will always be blue and shaped like an "M". Make your report simple. Reports such as "yellow at six o'clock", or "blue center" are all that are required. Do you understand what you are to do? (Pause)

All right--two more very important things before we start. First, you are to continue working at this task until you feel that you can not go on any longer because of tiredness. When you give this report, we will stop for the day. It is important that you do not stop for any other reason before this point occurs. Secondly, during the time you are working, you may experience shifts in your attitude toward the task, some sort of organic discomfort, or you may feel awkward, nervous or restless, sleepy, or you may well experience minor and transitory tiredness. In any case, anything that you experience of this sort I want you to report immediately. Just talk out loud and describe the change as accurately and completely as you can and I'll make a note of it. (Pause).

Remember now, you are to report the presence of a target by pressing the signal key as quickly as you are able, then you are to report the color and position of the light. You are to continue doing this until you feel that you are too tired to continue. Remember, do not stop before this point occurs for any reason."

After the formal directions were given, the task was discussed with the subject on an informal basis and any questions he posed were answered. The experimenters then started the apparatus, set the ambient conditions of phenomenal change, recorded the time, and ambient conditions of temperature and humidity.

During the 10th trial, the procedure followed was identical to that just described. However, when the subject became fatigued the experiment was not concluded. At this point, with the apparatus running, the following instructions were given:

"It will be necessary to continue the trial somewhat longer tonight even though I know that you want to stop now. I would like you to continue responding to the targets just as you have been doing and to do one additional thing. Periodically, I will ring a desk bell, and at this point, you are to report the intensity of your tiredness, any feelings of strain you may have or of discomfort, nervousness, etc. I would like you to estimate the length of time you have already served now, and then, if there are no questions, we will continue."

The subject was not warned beforehand of this post-fatigue experimental condition.

Results:

The relationship between the ambient conditions of change and the emergence of fatigue are presented graphically in Figures 77,78,79. The most general statement that can be made is that the ambient conditions have an effect upon the number of minutes a subject can work at a homogeneous task before becoming "too tired to go on." This becomes obvious when the graphs are studied individually. In all but one instance the fatigue produced in conjunction with the specific conditions cluster at a well defined place on the minute scale. In figure 77 the "phenomenal change 2" condition responses cluster at the low position of the scale, the "phenomenal change 12" condition at the high position of the scale, and the "phenomenal movement descending" condition responses at a position between the preceding. Graphs 78 and 79 show definite structuring according to the ambient phenomenal condition also. The responses of the subjects to the phenomenal change 2 condition of Figure 79 is the only exception to this rule. Another very general thing to be observed is that the condition bringing about the shorter duration, i.e. phenomenal change 2, is ordinarily very different in effect from the two conditions resulting in longer durations. This is most evident in Figures 78 and 79. In these two figures the "phenomenal change 12" and "phenomenal movement descending" conditions both occupy positions that are similar to one another and distinct from ambient condition "phenomenal change 2." Third, one should observe that very little variability exists between subjects regarding the number of minutes they are able to perform under a particular experimental condition of a particular experimental run, i.e. each sequence of trials in which the subject has served under each of the three conditions. The one exception again to this occurred during run 3 when the ambient condition was phenomenal change 2. Here we see a dispersion of performance that will be remarked upon later.

Despite these similarities however, an overall description of the interdependence between the ambient phenomenal variables on the one hand and the emergence of fatigue on the other is not easily made. The effect of the ambient conditions vary considerably from one experimental run to another. While this is not surprising since the same subjects were used throughout, it does make description of the phenomenal contribution less simple. It will be necessary to consider each run independently.

The results of the 1st run (Figure 77) show that with phenomenal change 2 as the ambient condition, fatigue emerged most quickly for each subject and that conversely, ambient phenomenal change 12 provided the condition featuring greatest immunity to fatigue for each subject. The second run (Figure 78) shows a reversal for each subject and for each ambient condition with one very minor exception. In this case it is phenomenal change 2, the "short" duration condition, that is related to the latest occurrence of fatigue and phenomenal change 12 becomes the ambient condition most conducive to fatigue. The third trial run (Figure 79) shows that the ambient conditions corresponding to "long" durations are about as effective as they were in the second run but that the phenomenal change 2 condition responses are too variable, to be characterized en toto.

The measurements made of temperature and relative humidity make it seem unlikely that the patternings can be accounted for by these ambient physical variables. The records reproduced to the sides of the plots do not show any patterns suggestive of those occurring within performance. Nor does an artifact in procedure seem to be involved since each subject served as his or her own control, the experimental orders were balanced, and each run for a given subject occurred during the same time of day.

One thing of minor interest is the correspondence between the subjects' estimations of the number of minutes of performance and the ambient phenomenal conditions employed.

Table 12 below shows that 7 out of 10 of the estimates were underestimations when the condition was "phenomenal change 2," the condition yielding shorter durations, while 7 out of 10 of the estimations were overestimations where the condition was "phenomenal movement descending," and 5 out of 9 overestimations when the condition was "phenomenal change 12," the latter two conditions yielding longer durations.

Table 12

ESTIMATED AND ACTUAL CLOCK TIME FOR 3 AMBIENT CONDITIONS.

A. "Phenomenal change 2" (a condition producing "short durations").

Subject	Trial	Number	Actual	Estimated	Direction of Estimations
	a	10th	101	95	- (6)
B	b	6th	132	120	- (12)
	c	1st	108	95	- (13)
	a	8th	164	115	- (49)
D	b	2nd	95	105	≠ (10)
	c	5th	153	130	- (23)
	a	8th	124	120	- (4)
R	b	4th	160	145	- (15)
	c	3rd	116	120	≠ (4)
	d	10th	129	135	≠ (6)
B. "Phenomenal movement descending" (a condition producing "long" durations.)					
	a	7th	77	65	- (12)
B	b	5th	120	145	≠ (25)
	c	3rd	123	135	≠ (12)
	d	9th	133	150	≠ (17)
	a	3rd	113	120	≠ (7)
D	b	4th	110	120	≠ (10)
	c	7th	142	116	- (26)
	a	1st	134	120	- (14)
R	b	9th	143	150	≠ (7)
	c	6th	94	100	≠ (6)
C. "Phenomenal change 12" (a condition producing "long" durations).					
	a	2nd	147	130	- (17)
B	b	4th	105	110	≠ (5)
	c	8th	123	150	≠ (27)
	a	6th	115	65	- (50)
D	b	1st	141	long time[1]	?
	c	9th	129	125	- (4)
	d	10th	80	90	≠ (10)
	a	2nd	136	90	- (46)
R	b	5th	87	105	≠ (18)
	c	7th	133	135	≠ (2)

≠ overestimations
-- underestimations

1. Subject unable to give an estimate, "time has no meaning to me here."

These results show that the conditions that should be producing long and short durations are actually doing so. These results in a way provide an independent validation of the experimental findings of Part 1. However, although the results in general are harmonious with what one would expect, on the basis of our knowledge of the effect of the ambient phenomenal condition, the theoretical importance of the findings are doubtful. Aside from the technique, i.e. asking the subject to pretend he is a clock, there is the obvious fact that the estimations showed considerable variability in "amount of error." For example, in the shorter duration condition 85% of the "error" was underestimation (122 minutes underestimation and 20 minutes overestimation, -122/142 = -85%), while in the longer duration condition the "error" was 62% overestimation (+84/136 = +62%) and 65% <u>underestimation</u> (-117/179= -65%) respectively. Also Table 13 shows that the overestimations and underestimations are related to the clock length of the trial.

Table 13

OVERESTIMATIONS AND UNDERESTIMATIONS WITH TRIALS OF VARIOUS LENGTHS

Minutes to fatigue	Direction of Estimation	Minutes to fatigue	Direction of Estimation	Minutes to fatigue	Direction of Estimation
77	- (12)	115	- (50)	133	+ (2)
80	+ (10)	116	+ (4)	134	- (14)
87	+ (18)	120	+ (25)	136	- (46)
94	+ (6)	123	+ (12)	141	wanting *
95	+ (10)	123	+ (27)	142	-(26)
101	-(6)	124	-(4)	143	+ (7)
105	+ (5)	129	-(4)	147	-(17)
108	- (13)	129	+ (6)	153	-(23)
110	+ (10)	132	-(12)	160	-(15)
113	+ (7)	133	+ (17)	164	-(49)

+ overestimation

– underestimation

1. Subject unable to make an estimate."time has no meaning here".

Table 14 suggests that no one subject made an especially large or small contribution to the variance.

Table 14

DIRECTION OF ESTIMATION OF CLOCK TIME FOR 3 SUBJECTS UNDER ALL CONDITIONS

Trial Numer	Subject B	Subject D	Subject R
1	-(13)	wanting [1]	-(14)
2	-(17)	+(10)	-(46)
3	+(12)	+(7)	+(4)
4	+(5)	+(10)	-(15)
5	+(25)	-(23)	+(18)
6	-(12)	-(50)	+(6)
7	-(12)	-(26)	+(24)
8	+(27)	-(49)	-(4)
9	+(17)	-(4)	+(7)
10	-(6)	+(10)	+(6)

+ overestimation
- underestimation

1. subject unable to give an estimate, "time has no meaning to me here".

The results of the measurements of reaction time are shown in figures 50 through 76. Figures 50 through 75 show the simple reaction time for various subjects during the pre-fatigue condition. Since the subjects worked for varying numbers of minutes from trial to trial the responses are expressed as Vincent curves. The mean reaction time for each interval is plotted. Spontaneous pre-fatigue reports of discomfort, restlessness, etc. are also entered at the appropriate places. The post-experimental protocols (Figure 50 through 72 only), the ambient physical conditions, and the number of minutes occurring during each trial are included at the side.

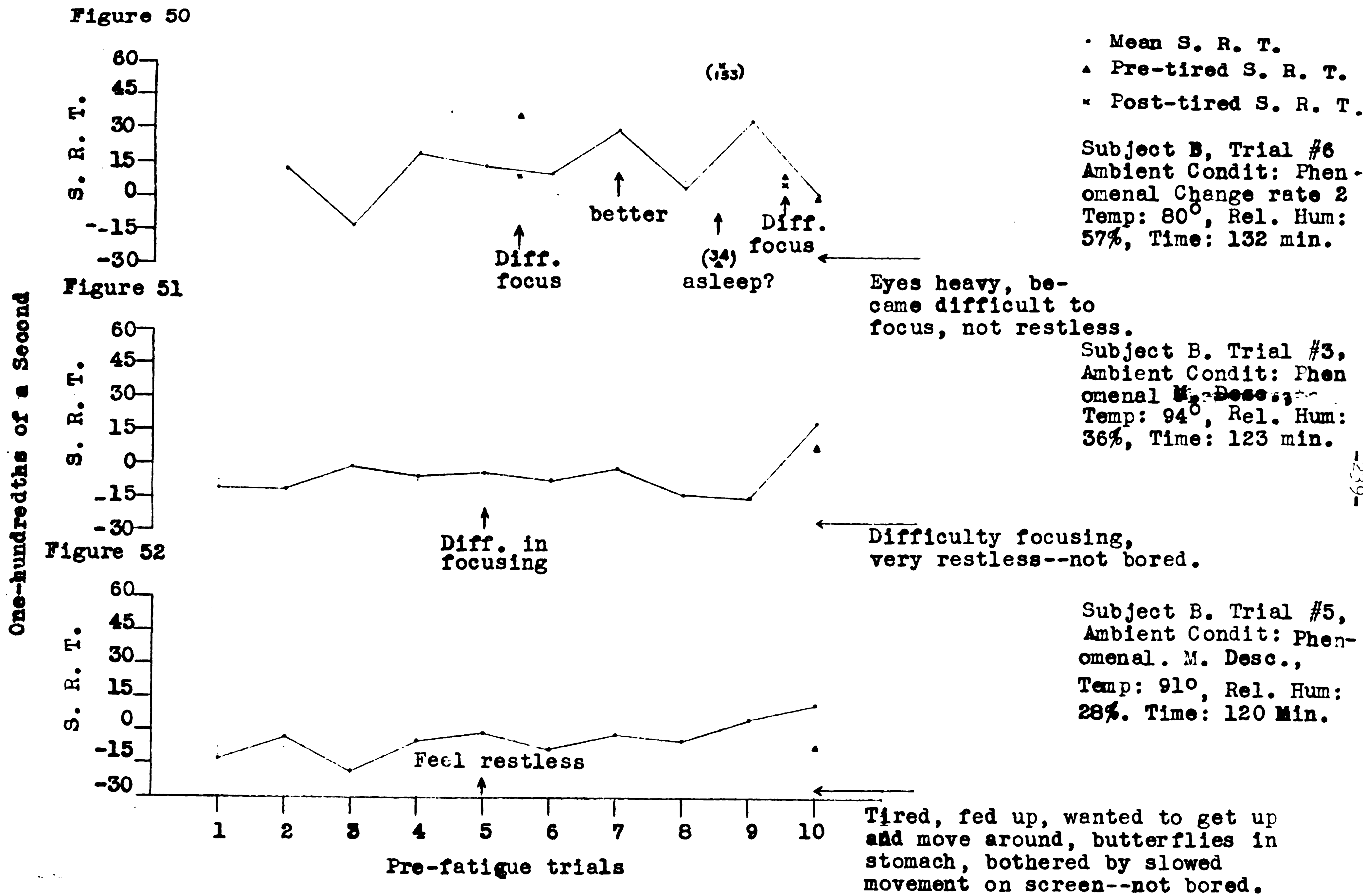
Comparing the pre-fatigue plots to one another does not produce anything approaching what could be called a "typical" pre-fatigue curve even though in a few cases the reaction times show a steady increase (Figures 52, 69, 75 most notably) or a steady decrease (Figure 56 especially). The plots of Figure 76 make this even more evident. Here we have graphed the mean of both the simple reaction times and verbal reaction times for all subjects under all conditions and find a notable lack of direction in both cases, an "averaging out" of the irregularities prominent in the individual figures. Similarly, peaks and troughs of response latency occur throughout the record without occupying a predictable position nor do the spontaneous reports appear to have a close relationship to the changes in reaction time. This is particularly evident when the three responses just anteceding a spontaneous report indicating tiredness are compared to the three made just after the same report. The preceding responses (shown in figures as small closed triangles) are of greater average latency in 7 of the cases and of less average latency in 9 of the cases relative to the responses made after the report (indicated by a small x). Nor can the reaction time preceding the point of fatigue be said to characteristically increase or decrease for the population. The small triangles associated with the 10th interval shows this clearly. Eleven of the averages are below, 10 are above, and 3 are identical to the mean of the last interval.

Looking at the data subject-wise, it is apparent that some individual differences in simple reaction patterns are present. Plots for subjects B (Figures 50 through 57, 74) and R (Figures 65 through 72, 75) vary appreciably between trials. Subject B sometimes responds consistently early and R occasionally very late. In contrast, the plots showing subject D's responses (Figures 54 through 64, 73) present a more homogeneous picture. There is typically a slowness about midway in the trial coupled with equally adequate responses at the beginnings and ends of the trials.

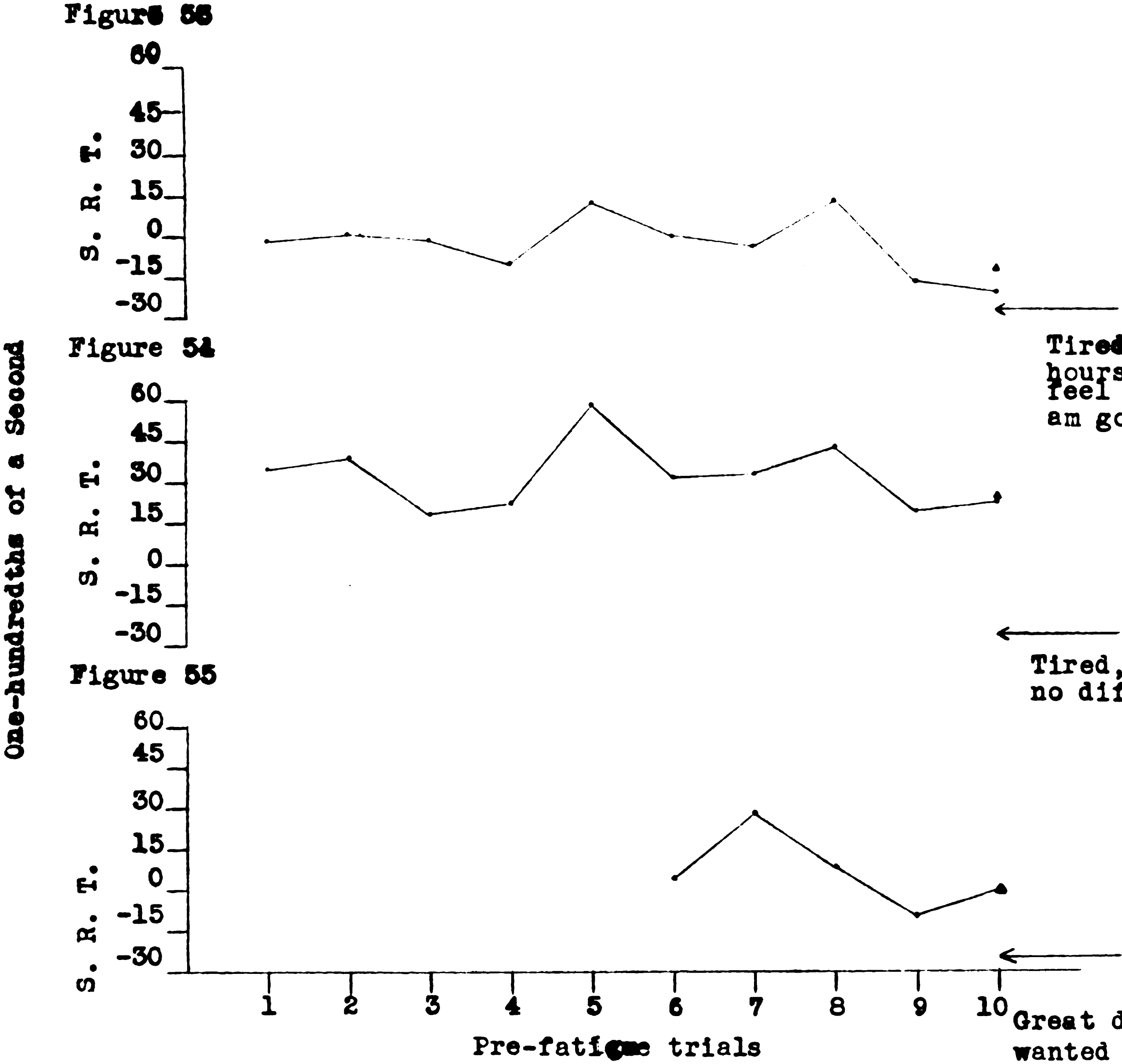
Temperature, relative humidity, and clock length of the trial again have no apparent effect, either upon the responses en toto or upon the responses of individual subjects.

The post-experimental protocols are interesting in that they point up the number of manifestations that may accompany fatigue. Difficulty in focusing, feelings of restlessness, "nervousness," tenseness, sleepiness, inadequacy and confinement are mentioned. The pre-fatigue reports, moreover, show that the symptom finally prevailing need not reflect those anteceding it. The symptoms in fact frequently shift locus. Also the fatigue complaints do not occupy anything approaching a fixed position either in terms of the trial as a duration of activity or in terms of minutes of work. The symptoms appearing pre-fatigue do not seem to have predictive value.

The post-fatigue trials produced markedly different response patterns from those of the pre-fatigue trials. In all 3 subjects (Figures 73 through 75), the average time for the simple and verbal reactions is both longer and the performance more erratic than those preceding fatigue. Each subject shows an initial increase followed by a re-adjustment to the fatigue which is in turn followed by an abrupt increase in reaction time. In all cases there is visable a marked inadequacy of performance at the point at which the trial was discontinued.



Three figures showing the simple reaction times of individual subjects on single trials.



. Mean S. R. T.
▲ Pre-tired S. R. T.
x Post-tired S.R.T.

Subject B. Trial #7
Ambient Condit:Phenomenal M.Desc.,
Temp: 85°,Rel.Hum: 52%, Time: 77 min.

Tired, had 3 hours sleep, feel as though I am going to fall asleep.

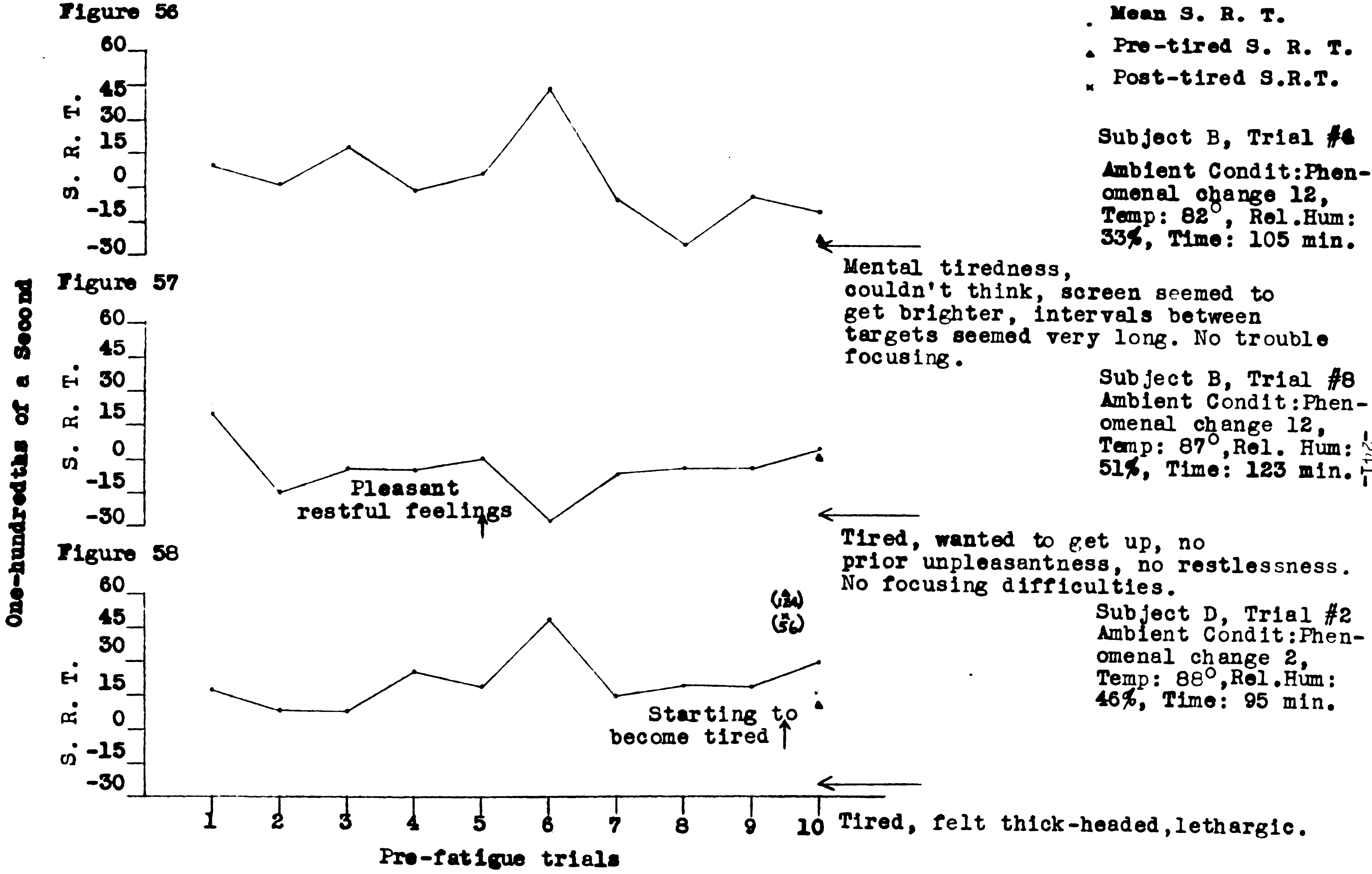
Subject B.Trial #9,
Ambient Condit:Phenomenal M.Desc.,
Temp: 80°,Rel.Hum; 57%, Time:133 min.

Tired, feel I was working at it, no difficulty with the task,however.

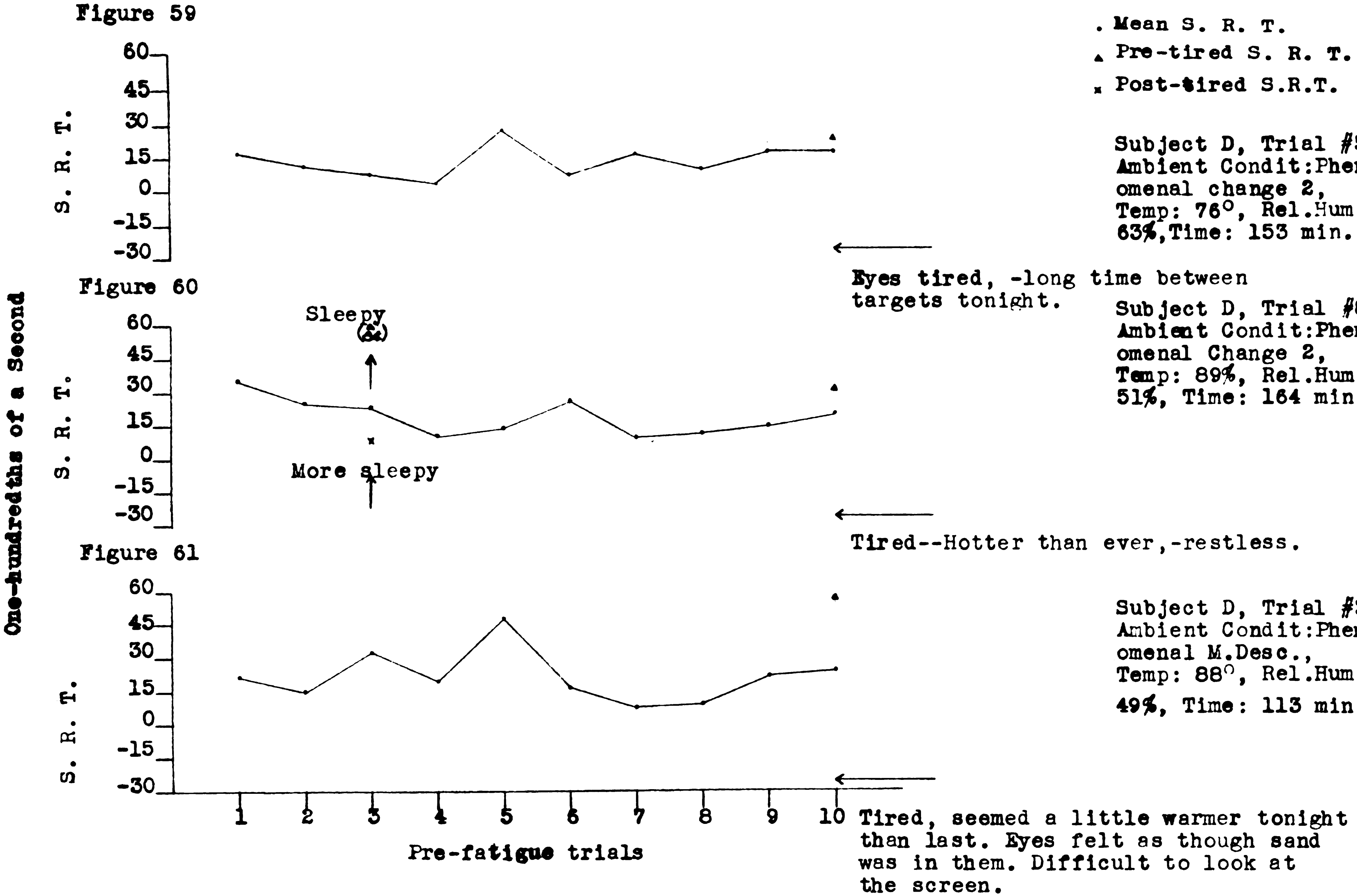
Subject B. Trial #2
Ambient Condit:Phenomenal Change 12,
Temp: 93°,Rel. Hum: 36%, Time:147 min.

Great difficulty in focusing and wanted to move. Great difficulty midway, intervals between lights longer than last.

Three figures showing simple reaction times of individual subjects on single trials.



Three figures showing the simple reaction times of individual subjects on single trials.

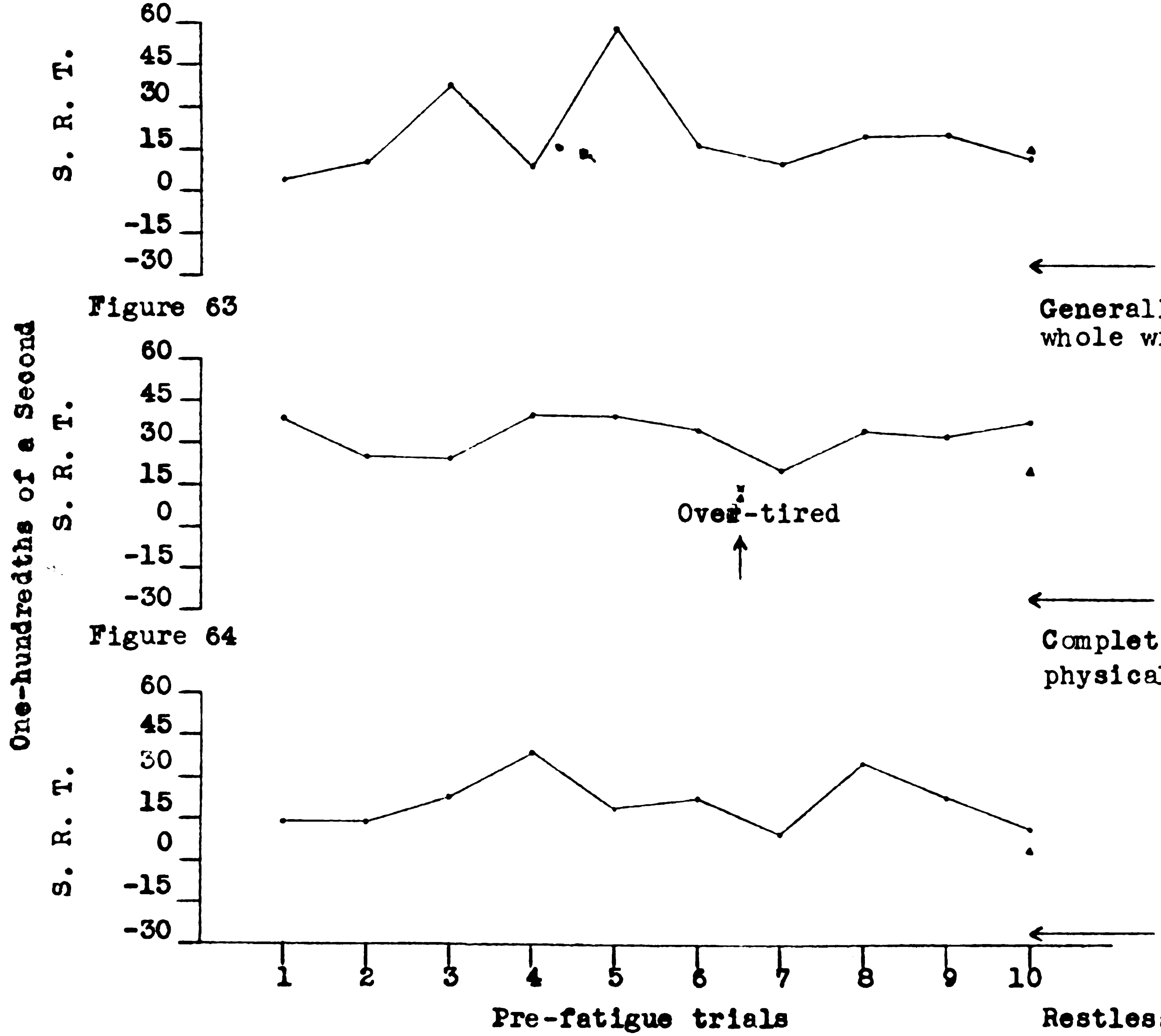


Three figures showing the simple reaction times of individual subjects on single trials.

Figure 62

Figure 63

Figure 64



. **Mean S. R. T.**

▴ Pre-tired S. R. T.

× **Post-tired S.R.T.**

Subject D, Trial #4
Ambient Condit:Phen-omenal M. Desc.,
Temp: 75°, Rel. Hum: **55%, Time:** 110 **min.**

Generally fatigued--fed up as a whole with the reporting.

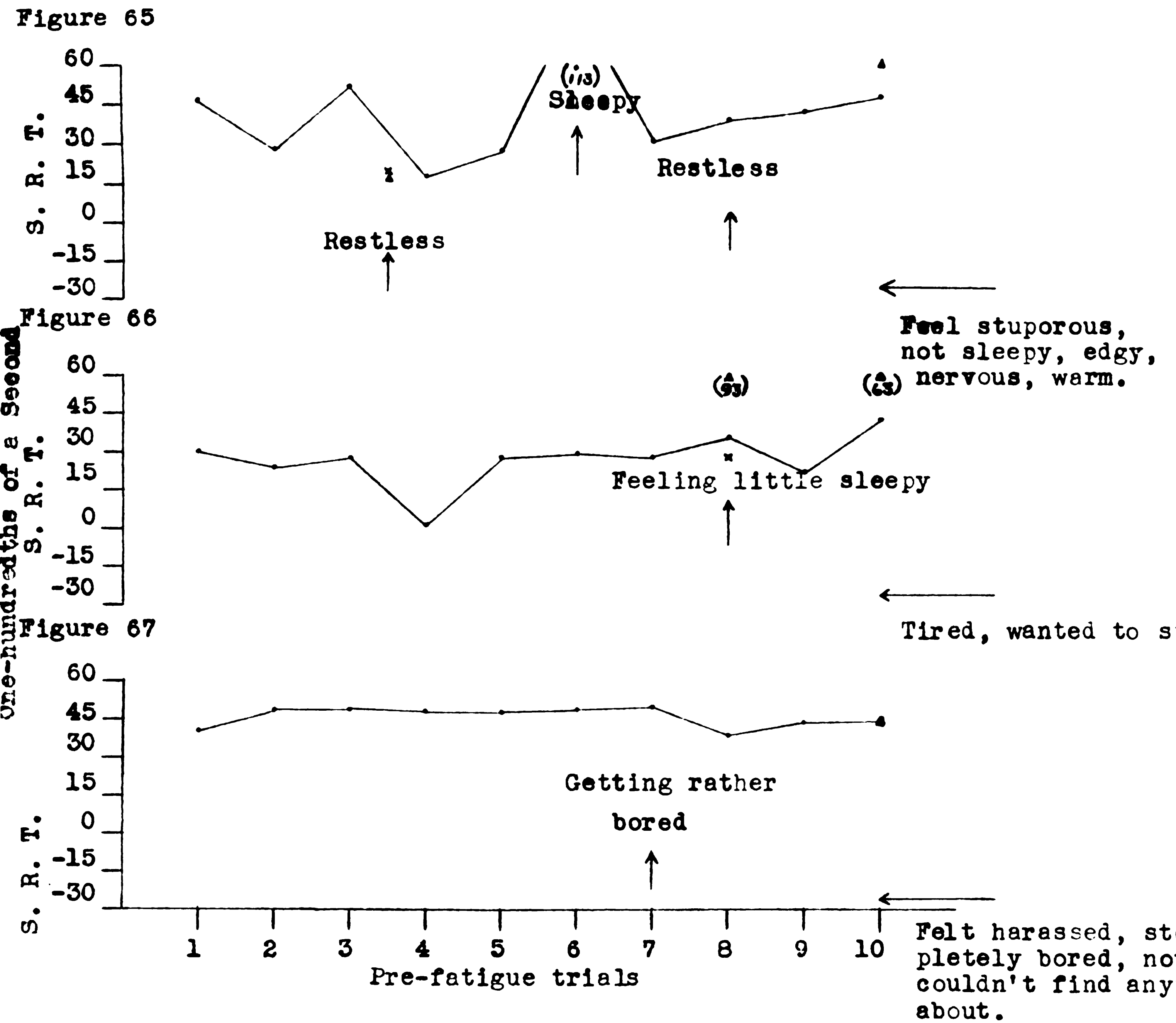
Subject D, Trial 7,
Ambient Condit:Phen-omenal M. Desc.,
Temp: 86°, Rel.Hum:
44%, Time: **142** min.

Completely tired, just like after physical labor.

Subject D, Trial #6,
Ambient Condit:Phen-omenal Change 12,
Temp: 88°, Rel. Hum:
43%, Time: 115 min.

Restless, hot and tired suddenly before stopping.

Three figures showing the simple reaction times of individual subjects on single trials.



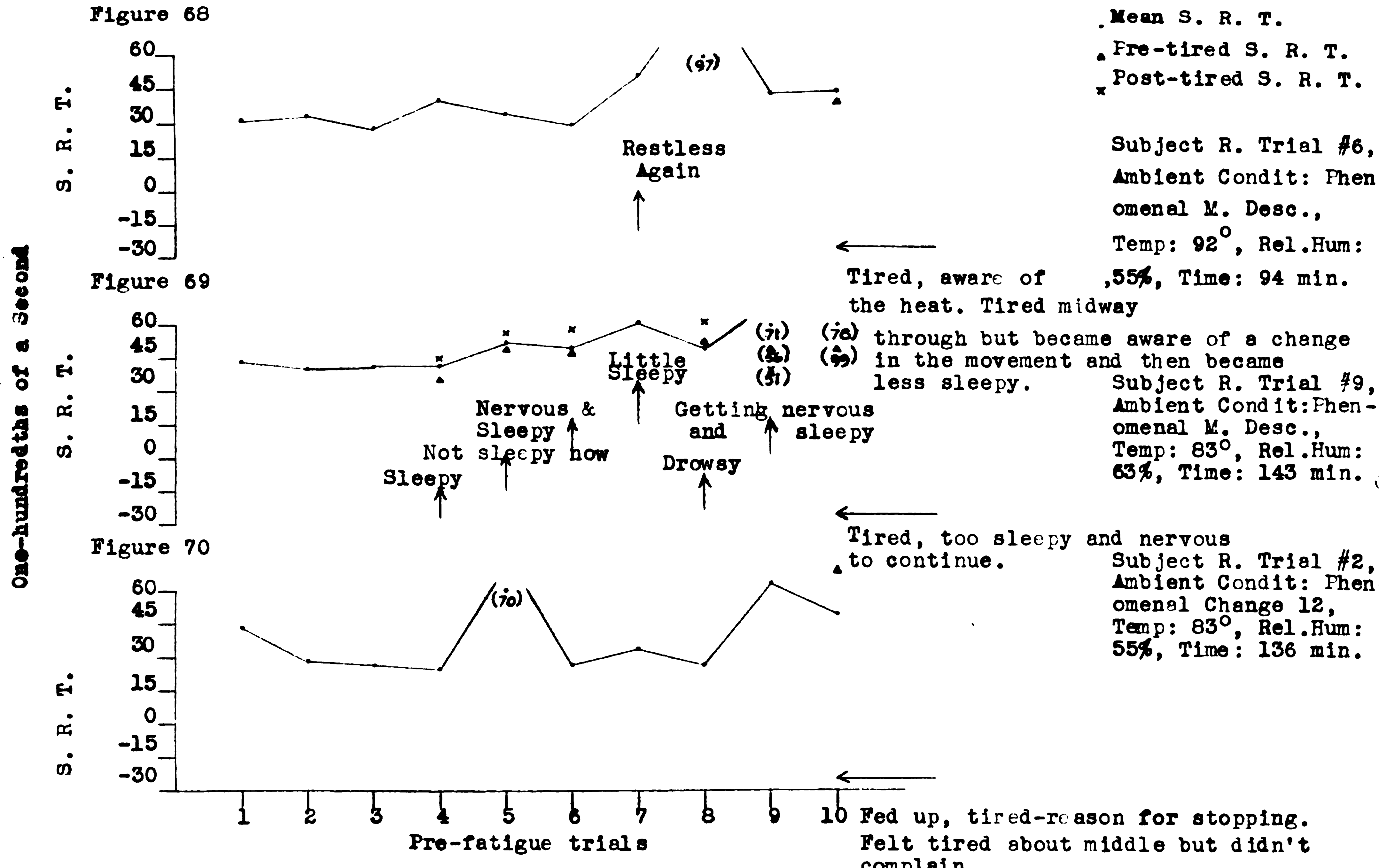
. Mean S. R. T.
▲ Pre-tired S. R. T.
x Post-tired S. R. T.

Subject R, Trial #3
Ambient Condit: Phenomenal Change 2,
Temp: 82°, Rel. Hum: 55%, Time: 116 min.

Subject R, Trial #4,
Ambient Condit: Phenomenal Change 2,
Temp: 80°, Rel. Hum: 63%, Time: 160 min.

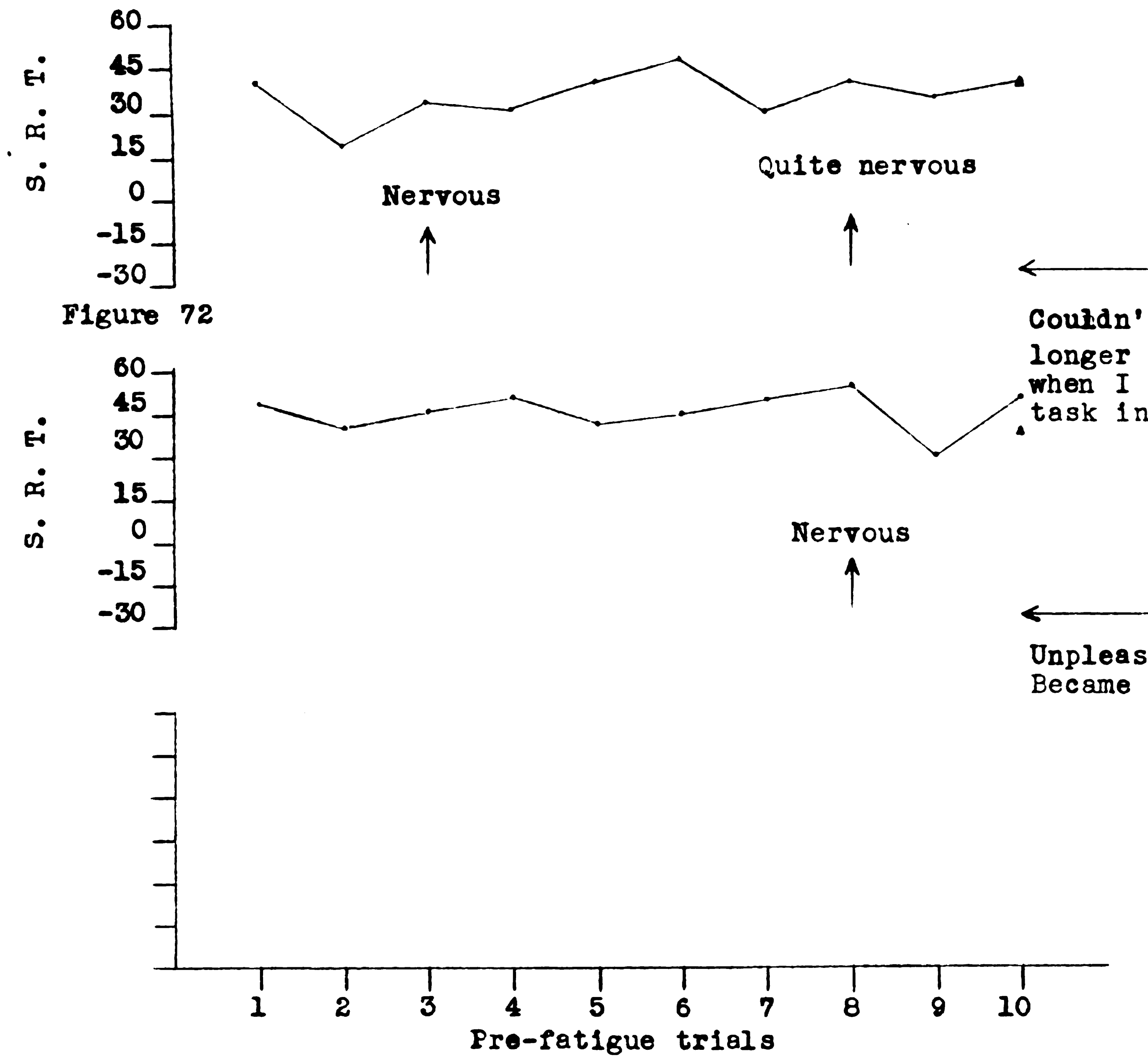
Subject R, Trial #8,
Ambient Condit: Phenomenal Change 2,
Temp: 88°, Rel. Hum: 46%, Time: 116 min.

Three figures showing the simple reaction times of individual subjects on single trials.



Three figures showing the simple reaction times of individual subjects on single trials.

Figure 71



* Mean S. R. T.
* Pre-tired S. R. T.
*Post-tired S. R. T.

Subject B. Trial #5, Ambient Condit: Phenomenal Change 12, Temp: 77°, Rel.Hum: 48%, Time: 87 min.

Couldn't concentrate any longer on the task, acutely restless when I stopped. Tired throughout the task in general.

Subject R. Trial #7, Ambient Condit: Phenomenal Change 12, Temp: 85°, Rel. Hum: 53%, Time: 133 min.

Unpleasant-nervous-very sleepy.
Became unnerved about missing lights.

Two figures showing the simple reaction times of individual subjects on single trials.

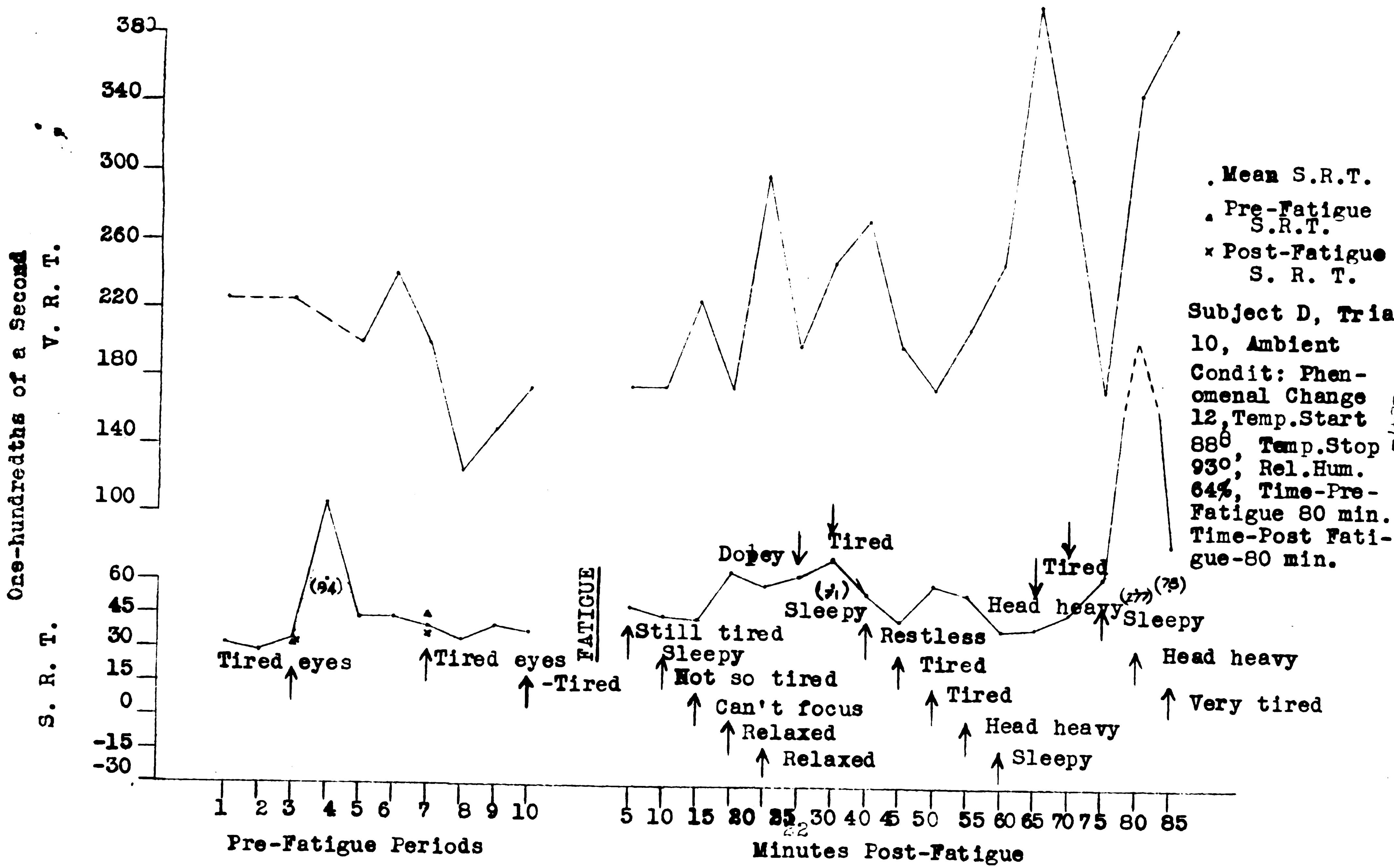


Figure 73 Means of Simple Reaction Times and Verbal Reaction Times for one subject under Pre- and Post-Fatigue Conditions.

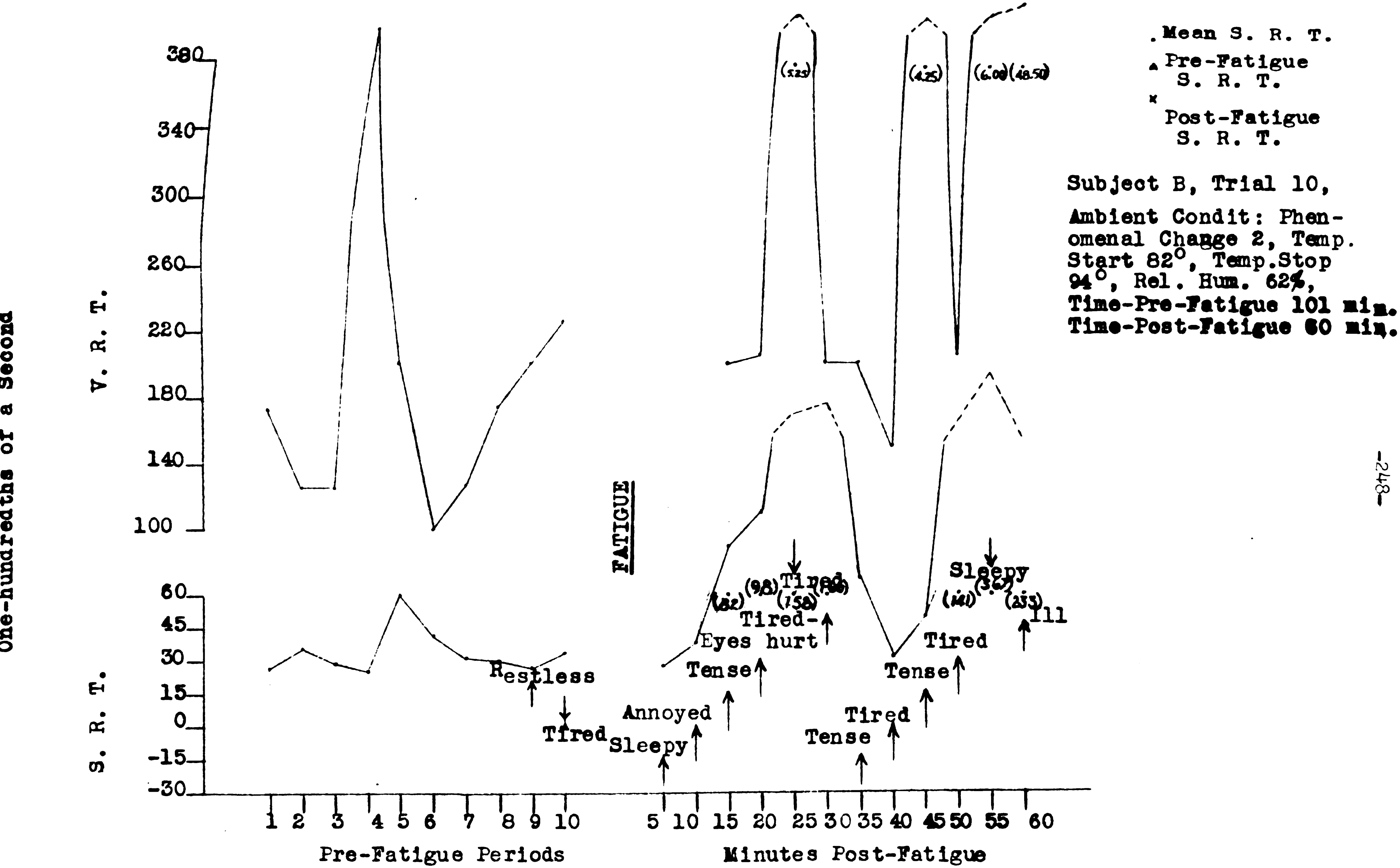


Figure 74 Means of Simple Reaction Times and Verbal Reaction Times for one Subject Under Pre- and Post-Fatigue Conditions.

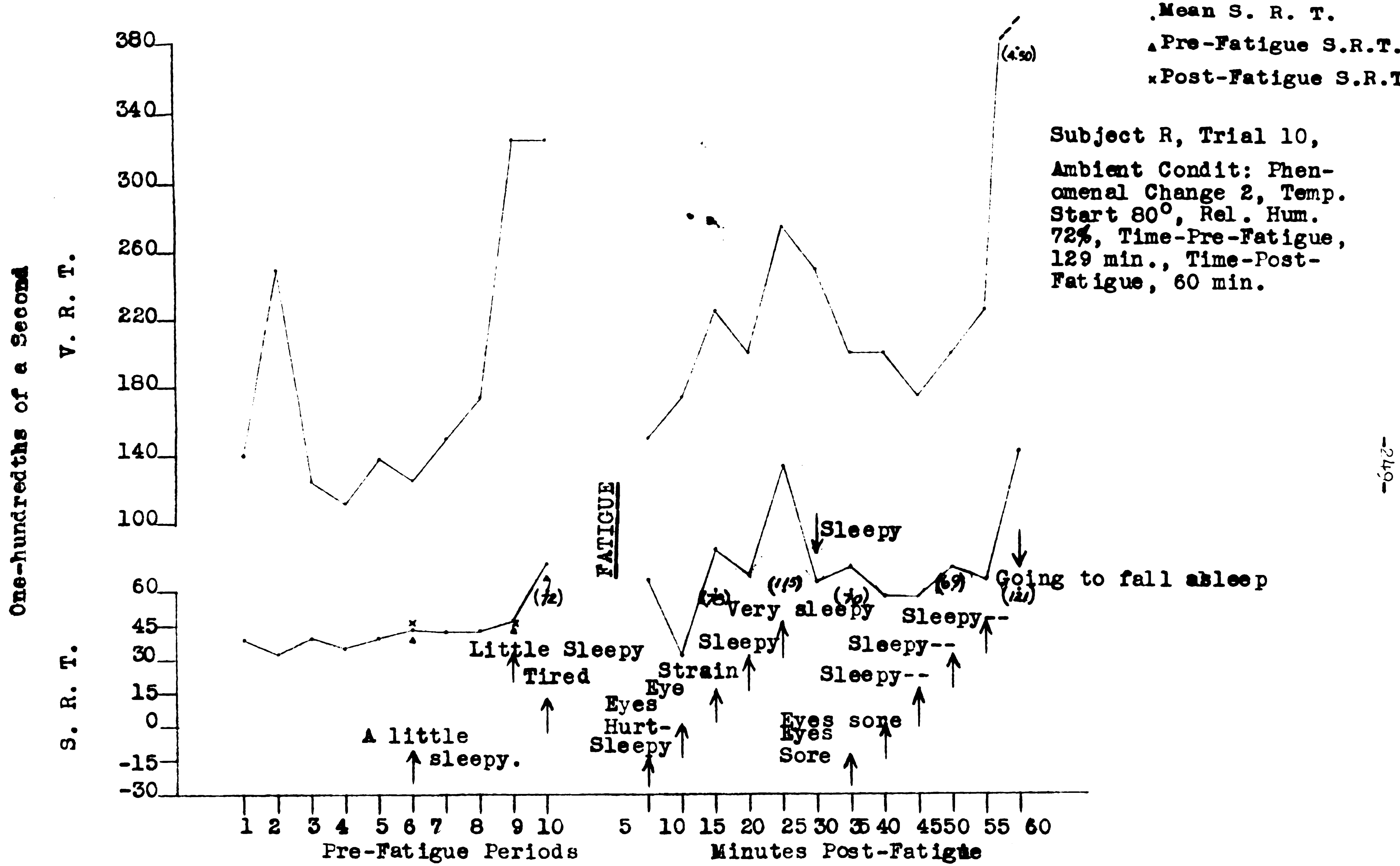


Figure 75 Means of Simple Reaction Times and Verbal Reaction Times for one Subject Under Pre-and Post-Fatigue conditions.

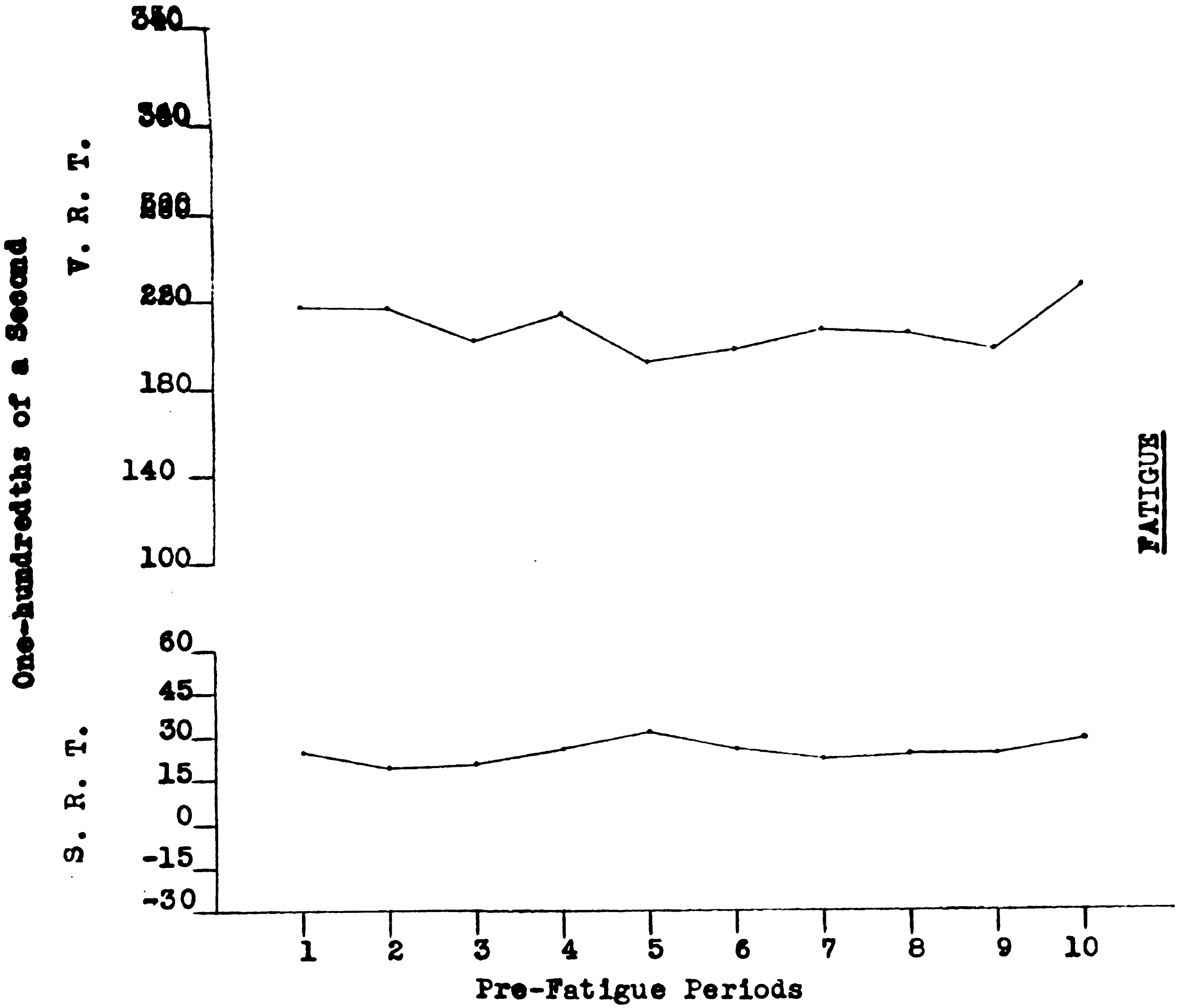


Figure 76 Means of Simple Reaction Times and Verbal Reaction Times for All Subjects Under all Conditions.

Ambient Phenomenal Conditions

		C.2	M. Desc.	C. 12
Tempt.	Subj. B	100	94	93
	Subj. D	88	88	91
	Subt. R	82	85	83
Relative Humidity	Subj. B	33	36	36
	Subj. D	46	[illegible]9	29
	Subj. R	55	46	55
Experimental Order	Subj. B	1	3	2
	Subj. D	2	3	1
	Subj. R	3	1	2

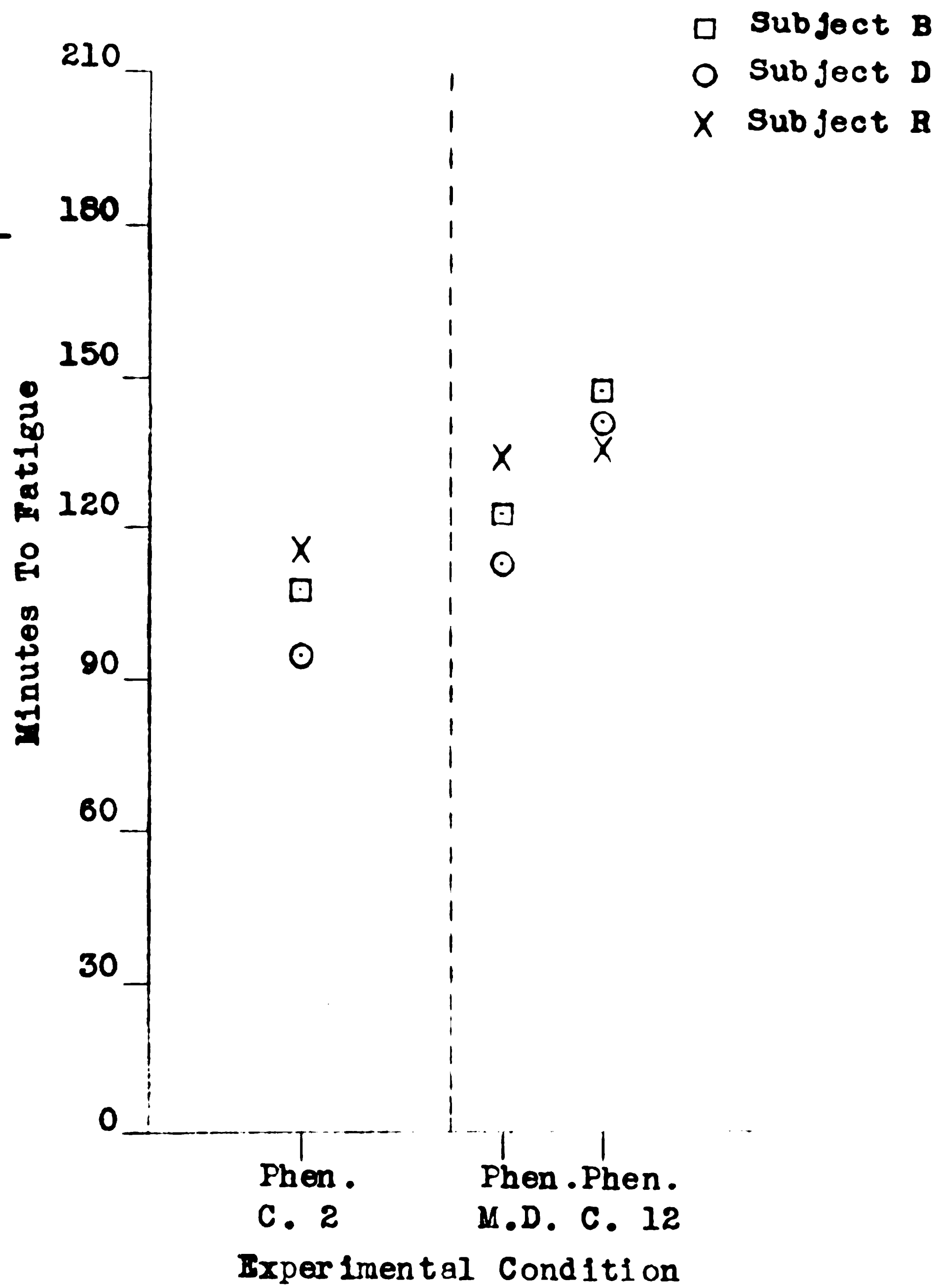


Figure 77 Number of Minutes to Fatigue in the First Experimental Run.

Ambient Phenomenal Conditions

		C.2	M.Desc.	C. 12
Tempt.	Subj. B	80	91	82
	Subj. D	76	75	88
	Subj. R	80	92	77
Relative Humidity	Subj. B	57	28	33
	Subj. D	63	61	43
	Subj. R	63	55	48
Experimental Order	Subj. B	6	5	4
	Subj. D	5	4	6
	Subj. R	4	6	5

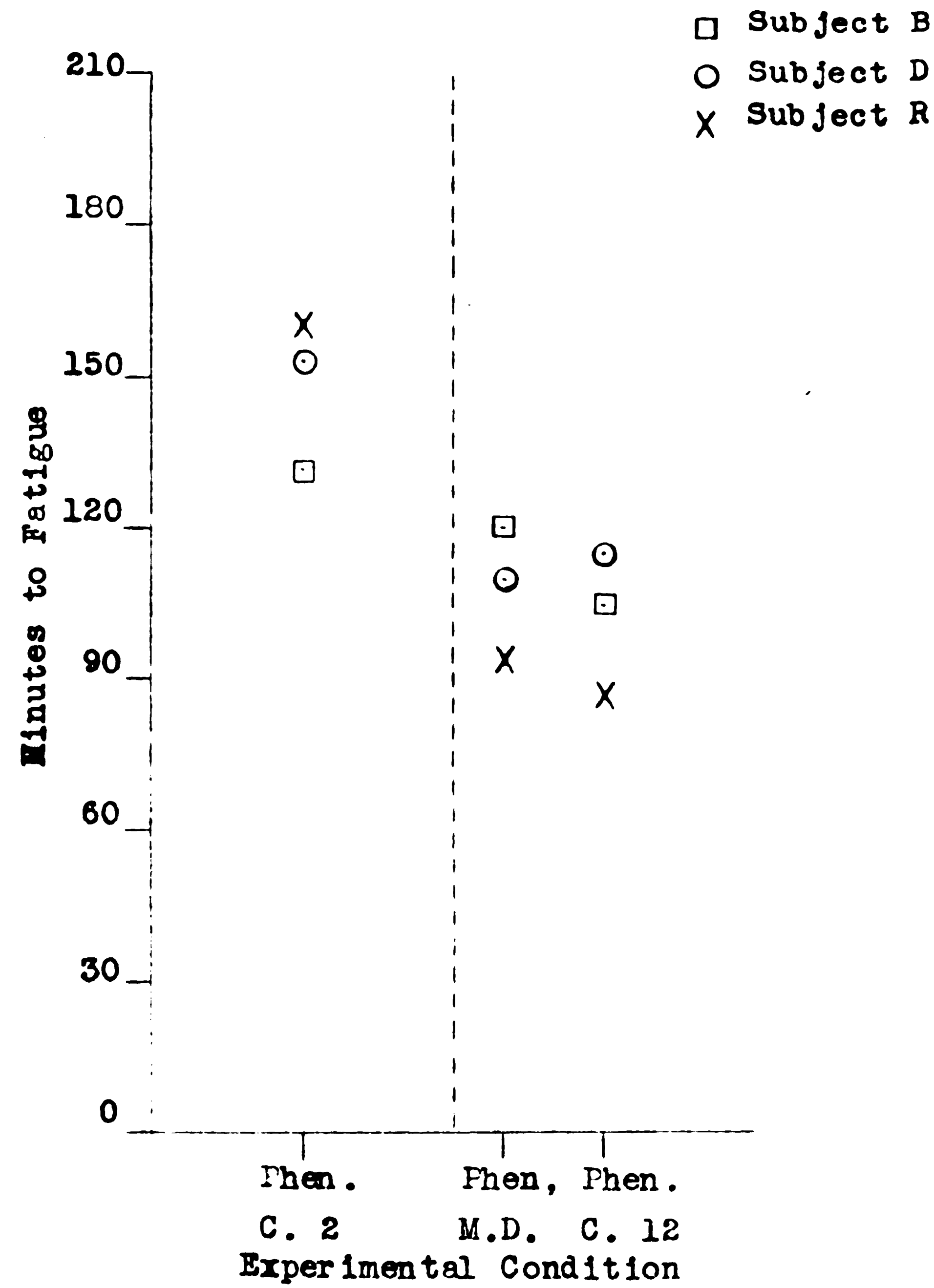


Figure 78 Number of Minutes to Fatigue in the Second Experimental Run.

Ambient Phenomenal Conditions

		C.2	M.Desc.	C. 12
Tempt.	Subj. B	82	80	80
	Subj. D	89	86	87
	Subj. R	88	83	85
Relative Humidity	Subj. B	62	57	51
	Subj. D	51	45	46
	Subj. R	46	63	53
Experimental Order	Subj. B	10	9	8
	Subj. D	8	7	9
	Subj. R	8	9	7

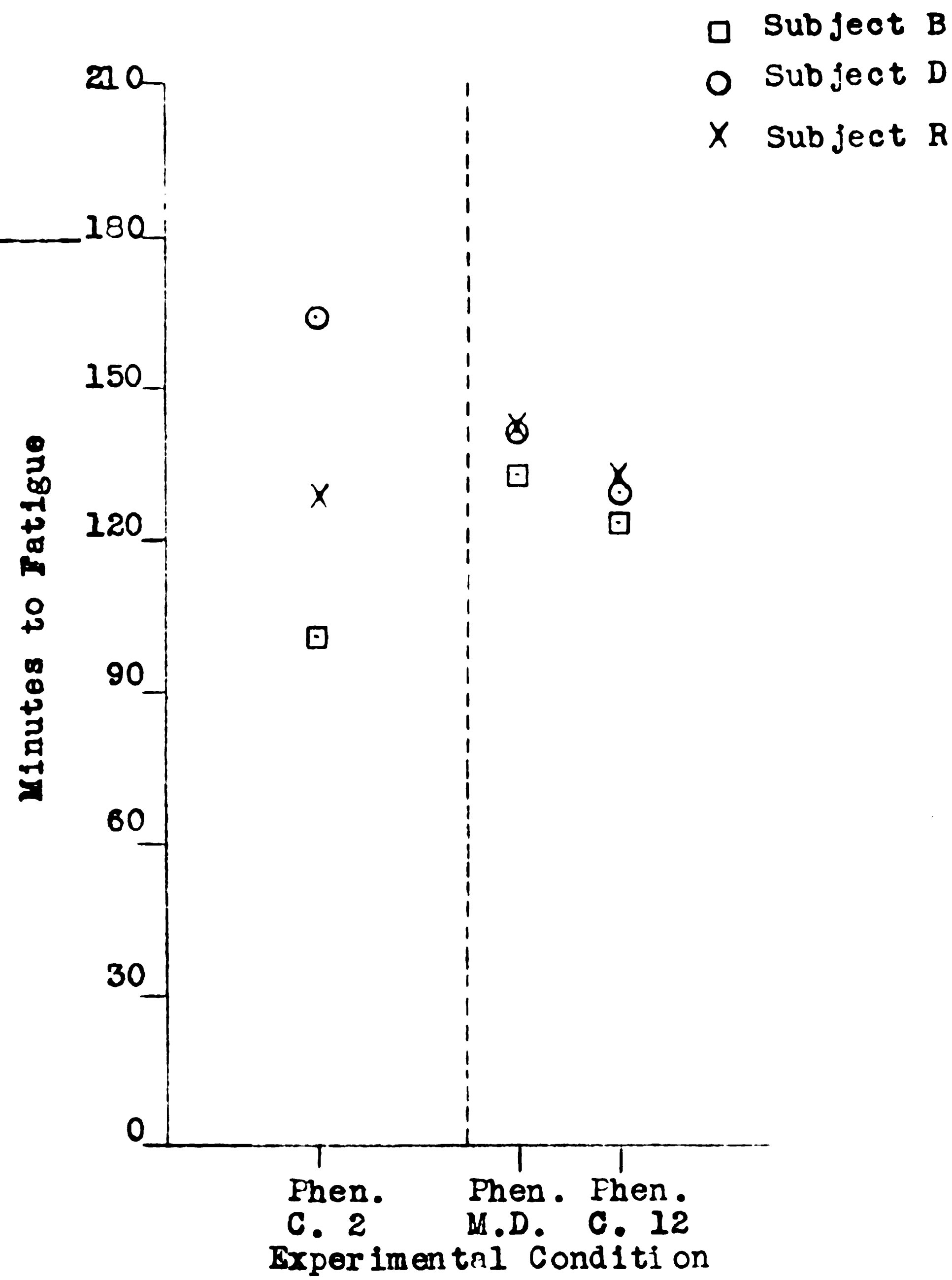


Figure 79 Number of Minutes to Fatigue in the Last Experimental Run.

CHAPTER IX

CONCLUSIONS AND DISCUSSION

Conclusions and Discussion:

Hypothesis 1 states that, "fatigue on a given task will develop as a function of the ambient conditions of duration." Since it is empirically known that the experience of duration is dependent upon the particular conditions of ambient change defining the duration (part 1), this is equivalent to saying that fatigue will develop as a function of the phenomenal conditions of change imposed.

The bulk of the data shows that this was the case in fact. In the experiment just reported each of the 3 experimental runs utilized 3 conditions of phenomenal change as the background conditions for a task. Two of these conditions were of a type that were known to produce "long" durations and one that was of a type that produced a "short" duration. Although the information we have concerning the functioning of the conditions with respect to duration is not of the best sort, apparently the ambient variables had the predicted effect. That is to say, the "long" ambient conditions did impose overestimations of time and vice versa. Granting this, the relationship between the ambient phenomenal conditions and the emergence of fatigue shows the anticipated interdependence. In every case the response to the ambient conditions imposing "long" phenomenal durations are distinct from that imposing a "short" phenomenal duration. In the first run the rapid phenomenal changes brought about fatigue more slowly, in the second run more rapidly, and in the third run the "long" conditions functioned more homogeneously than the "short" duration condition. Secondly, the invariance between the conditions with respect to order reflects an independence. It was mentioned before that although the method followed did not permit fine comparisons to be made between conditions, the "long" duration condition "phenomenal movement descending" would probably be somewhat less effective in producing long durations than the condition "phenomenal change 12." We find that this is borne out in the data of the graphs. The effectiveness of the phenomenal movement descending condition always lies somewhere between the two conditions. Thus, in the first run where the long duration conditions were ineffective in producing fatigue, it lies below phenomenal change 12. And, in the second and third runs, as the "long" ambient conditions become more effective in producing fatigue, the phenomenal movement descending condition lies above the phenomenal change 12 condition. <u>These facts lead to the conclusion that hypothesis 1 has been confirmed.</u>

The structure of the data points out that we are dealing with a subtle relationship however. Despite the confirmation of the hypothesis, apparently the data does not tell us much about the general nature of the interdependence between phenomenal change and the emergence of fatigue. The study is too fragmentary to venture even a hypothesis. A thoroughgoing understanding of the relationship between phenomenal change and fatigue must await further study. In this regard particular attention should be directed to the following things: a) fixing the functional dependencies by using additional subjects, b) investigating the tremendous shift in the effectiveness of the ambient phenomenal conditions, i.e. the change in performance resulting from practice, by running more trials per subject, and c) a test of the hypothesis under simpler experimental conditions, e.g. producing changes, durations, and fatigue using an intermittent visual stimulation.

On a theoretical level the study points out the feasibility of employing a purely phenomenalogical approach for the study of problems of this sort. Experience need not be "subjective" and without a place in science nor need it be thought of as a "byproduct" having no place in a casual chain leading to an understanding of human activity. Perhaps one should go even further and say that it points up the necessity of approaching personal behavior by a mapping out of the interdependencies within experience. One should not lose sight of the fact that, whatever the limitations of the study are, and, even though the study is essentially incomplete, it is probably the <u>first</u> successful investigation ever undertaken into the mechanisms underlying fatigue itself. Moreover, this approach would seem to open the possibility of measuring processes such as fatigue. It does not take a great leap in imagination to see that a thoroughgoing knowledge of the interdependencies between phenomenal change and fatigue would in fact allow for measurement, since phenomenal change is eminently capable of measurement. Nor does it demand wild fantasy to understand that measurement would in turn allow for the eventual statement of fatigue in terms of external situations. The relationship between external events and phenomenal change present no insurmountable scientific problem. Also, if one would establish the proper interdependencies it might allow for a statement of and a study of personal inadequacy in terms of physiological functioning. In the present instance, a thoroughgoing knowledge of the relationship between fatigue and phenomenal change such as single flashes could mean that, via well established laboratory techniques, one might get direct information regarding the basic neurophysiology of fatigue. Phenomenal changes are essentially abruptions occurring somewhere within the organism. Flashes are related in turn to patterns of neural discharge that have been actually extensively studied at the eye (by several techniques) within the optic nerve, and at the optic cortex.[1] Through the use of intermittent visual stimulation having various phenomenal characteristics, i.e., various rate of change and producing various patterns of nervous discharge and abruptions in the pattern during prolonged

1. See S.H. Bartley, "The Psychophysiology of Vision," in Handbook of Experimental Psychology, ed. by S.S. Stevens (New York: John Wiley and Sons, Inc., 1951), pp. 921-984.

activity, one might arrive at the "ultimate" scientific understanding of fatigue.

Hypothesis 2 predicts that "the emergence of fatigue will detract from the adequacy of performance of a reaction time task." The results reported indicate that in every case the two types of reactions both greatly slowed and became much more erratic than those preceding fatigue. Because this is so, it is concluded that hypothesis 2 has been confirmed.

This is in accord with what one might have inferred from the studies previously reviewed under the heading Motor response latency, accuracy of discrimination, and fatigue. It is however probably the first time that the deterioration of an overt response has ever been successfully related to tiredness in an empirical situation. Ordinarily, symptoms of inadequacy found in performance are a priori defined as fatigue, or, a priori defined to be resultants of impairment of peripheral or central nervous structures (i.e. as "local" or "mental fatigue".) Bartley and Chute[2] have elsewhere discussed the violence that such definitions have done to

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2. Bartley and Chute, op. cit.

to the progress of psychology as a science.[3]

Aside from confirming the hypothesis, the results of the reaction time measurements confirm several of the contentions held by Bartley and Chute regarding the overall characteristics of the fatigue process. The frequent shift in locus of the spontaneously reported symptoms and frequent lack of relation between the pre-fatigue and fatigue symptom justifies their contention that "Fatigue is never specific to a given body member."[4] The measurements also indicate that there is in fact a disorganization associated with fatigue. This is clearly manifested in all the results since the post-fatigue performance of every subject fulfilled the directions must less adequately than that preceding fatigue at any given point.

The results of this part of the experiment permit us to go somewhat beyond Bartley and Chute's initial statement of

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3. A puzzle Lincoln posed to a group of ardent reformers makes this point in a homey way. Failing by argument to show what he considered to be the lack of merit in a legal proposal to solve a pressing problem, he asked, "Now if I have a cow and add an extra leg how many legs will the cow have?" To the unanimous reply of "five" Lincoln said, "No, No, No, Gentlemen, the cow would still have four. My decision can make no difference to the cow at all."

While one may grant that the definition of words is not the province of any one individual, and granting that any science is simply the problems that its members choose to investigate, still common words, overlapping and awkward as they are, must have somewhere had an empirical content prior to psychology. Definitions dealing with well established "matter of fact" signs might better aim to clarify rather than wholly create meanings.

4. Bartley and Chute, *op. cit.*, p. 55.

disorganization, however. We shall do so because in science it is always desirable to make implicit meanings explicit. Disorganization in a psychological sense can well be defined as "the occurrence of response, behavioral or otherwise, that is not compatible with the expressed or observed intention of the organism." The degree of disorganization can be said to be low when the probability of finding a number of such responses is negligible and high when the probability of finding incompatability approaches certainty. The words "expressed or observed intention" should be taken to refer to some standard operationally definable such as the acceptance of a set of instructions in the case of expressed intention, or to something such as a productivity criterion in the case of observed intention.

CHAPTER X

SUMMARY

Summary

Fatigue is one of the oldest and most difficult problems faced by scientific psychology. Over the years various definitions and investigations of "fatigue" have been made. Nevertheless it has only been recently that Bartley and Chute separated this problem from the related phenomena of impairment and performance decrement. In the investigation undertaken here Bartley and Chute's criteria for "fatigue" was put into service. This criteria demands that any investigation into fatigue must deal with the presence of "tiredness". Starting from this point fatigue was operationally defined as the point at which the subject reported that he was "too tired to go on." Other possibilities of operational definition were discussed and discarded.

The aims of the investigation were two-fold. The studies aimed to investigate whether 1) the emergence of fatigue could be related to ambient phenomenal conditions of duration and change, and, 2) the emergence of fatigue has a counterpart in overt performance.

The tests were conducted in a laboratory setting featuring 1) an apparatus known to produce various phenomenal changes and durations at various levels of operation and 2) an apparatus producing a task. The change-duration mechanism was in fact a large kaleidoscope whose effect was projected on a screen. The kaleidoscope was adjusted

in two of the experimental conditions at a rapid change rate and in one condition at a slow change rate. The rapid change rates were known to produce long durations and the slow change short durations. The change on the screen served as the ambient phenomenal condition for the fatigue producing task. The task was produced by a device projecting various types of visual targets on the same screen. The task elicited overt performance that was expressible as simple and verbal reaction times.

Three paid subjects were used and the pattern of their responses confirmed both hypotheses. The results showed that 1) fatigue did develop as a function of ambient conditions of change-duration, and that 2) fatigue did lead to inadequate performance on the task. These represent the first successful studies of fatigue.

In the case of the 1st hypothesis the structure of the results both raised a number of questions answerable only by further experimentation and pointed up the desirability of attacking such problems via the establishment of functional interdependencies within experience. The ramifications of such an outlook were discussed.

In the case of the 2nd hypothesis the results also lead to additional conclusions. They both indicated that certain of Bartley and Chute's notions of fatigue were adequate and also allowed for an explicit statement respecting the functional characteristics of disorganization.

APPENDIX

Appendix

M.L. Nelson[1] investigated the effect of change upon reproduced durations. In her experimentation the subjects were required to reproduce an "empty" interval having the phenomenal duration of a standard interval embodying various levels of change. The changes in the standard intervals were achieved by interrupting a lighted aperature 2, 3, 4, or 5 times. The intervals so interrupted were of 6 different clock lengths, namely, 3, 6, 12, 18, 30, and 60 seconds. The results for her two subjects are given in Table 15[2] and 16[3]. In the columns headed "average" are recorded the effect due to filling. This effect was found by subtracting the constant error, when both the standard and comparison were empty, from the error in comparing when one of the intervals were filled. Ten reproductions were taken for each character of filling under each interval length. It will be noticed that all the errors are positive, indicating --as per the "Theory of Phenomenal Duration"-- that "filled" intervals were always phenomenally longer than those unfilled. It can also be noted that as the filling increased so, in general, did error. Figure 80[4] portrays in graphic form the regularity of the relationship.

1. M.L. Nelson, "Visual Estimate of Time," Psychol. Rev., IV(1902), pp. 447-459.
2. Ibid: p. 456.
3. Ibid: p. 457.
4. Ibid: Data from pp. 456-457

Table 15

THE EFFECT OF VARIOUS LEVELS OF FEELING UPON THE STANDARD ERROR OF SUBJECT R's REPRODUCTION.

Subject R.

Interval	No. of Lights	Average	M.V.%	Median	M.V.%
3 secs.	2	3.94	10	4	9
	3	4.24	24	4	25
	4	4.71	15	4.7	14
6 secs.	2	6.28	16	6	16
	3	6.88	20	6.5	20
	4	8.82	16	8.4	16
	5	8.80	15	9.2	14
12 secs.	2	10.62	17	9.8	17
	3	10.96	13	10.4	10
	4	12.88	9	12.2	9
	5	13.38	8	13.8	7
18 secs.	2	13.24	16	13	15
	3	13.46	22	13.3	21
	4	16.44	13	17.3	12
	5	14.10	9	13.6	8
30 secs.	2	20.04	16	19.1	17
	3	20.22	23	19	20
	4	19.66	20	16.6	29
	5	24.58	26	23.9	22
60 secs.	2	32.84	26	28.7	26
	3	35.90	35	30.9	37
	4	39.76	19	40.1	19
	5	35.56	19	32.7	16

Table 16

THE EFFECT OF VARIOUS LEVELS OF FEELING UPON THE STANDARD ERROR OF SUBJECT Rd's REPRODUCTION

Subject Rd.

Interval	No. of Lights	Average	M.V.%	Median	M.V.%
3 secs.	2	3.74	19	3.8	18
	3	4.56	13	4.5	13
	4	4.28	10	4.4	10
6 secs.	2	4.80	8	4.8	6
	3	6.68	17	6.9	16
	4	7.44	16	7.1	15
	5	8.36	12	8.7	12
12 secs.	2	10.07	14	10	14
	3	10.34	19	9.3	9
	4	11.11	22	9.9	11
	5	11.48	16	11.6	10
18 secs.	2	11.05	12	10.3	14
	3	13.83	11	14.35	9
	4	12.76	14	13.8	11
	5	15.35	12	15.3	10
30 secs.	2	17.41	14	16.3	14
	3	18.17	13	17.75	13
	4	17.99	18	16.35	16
	5	18.63	11	19.4	16
60 secs.	2	30.64	12	30.4	11
	3	34.56	16	34.3	17
	4	30.71	11	29.9	11
	5	33.54	17	34.2	16

Nelson also studied the effect of filling in longer intervals. Intervals of 30, 60, 120, 240, 360, and 600 seconds were "filled" by having a light flashing every half second in the observed aperature. These intervals were used both as the standards and as comparison materials for "empty" intervals. The results were rather inconclusive as graph 81 and 82 [5] will testify. She mentions that the experimentation using the longer intervals was generally unsatisfactory because of the difficulty in maintaining attention. We of course found the same thing true when intervals long in clock length were used. M.L. Nelson was sharply criticized for using intervals longer than 4 or 5 clock seconds without providing something to keep their attention occupied.[6]

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5. Ibid: Data from pp. 449-453.

6. W. Lay, "Imagry," Psychol. Rev., X(1903), pp. 422-425.

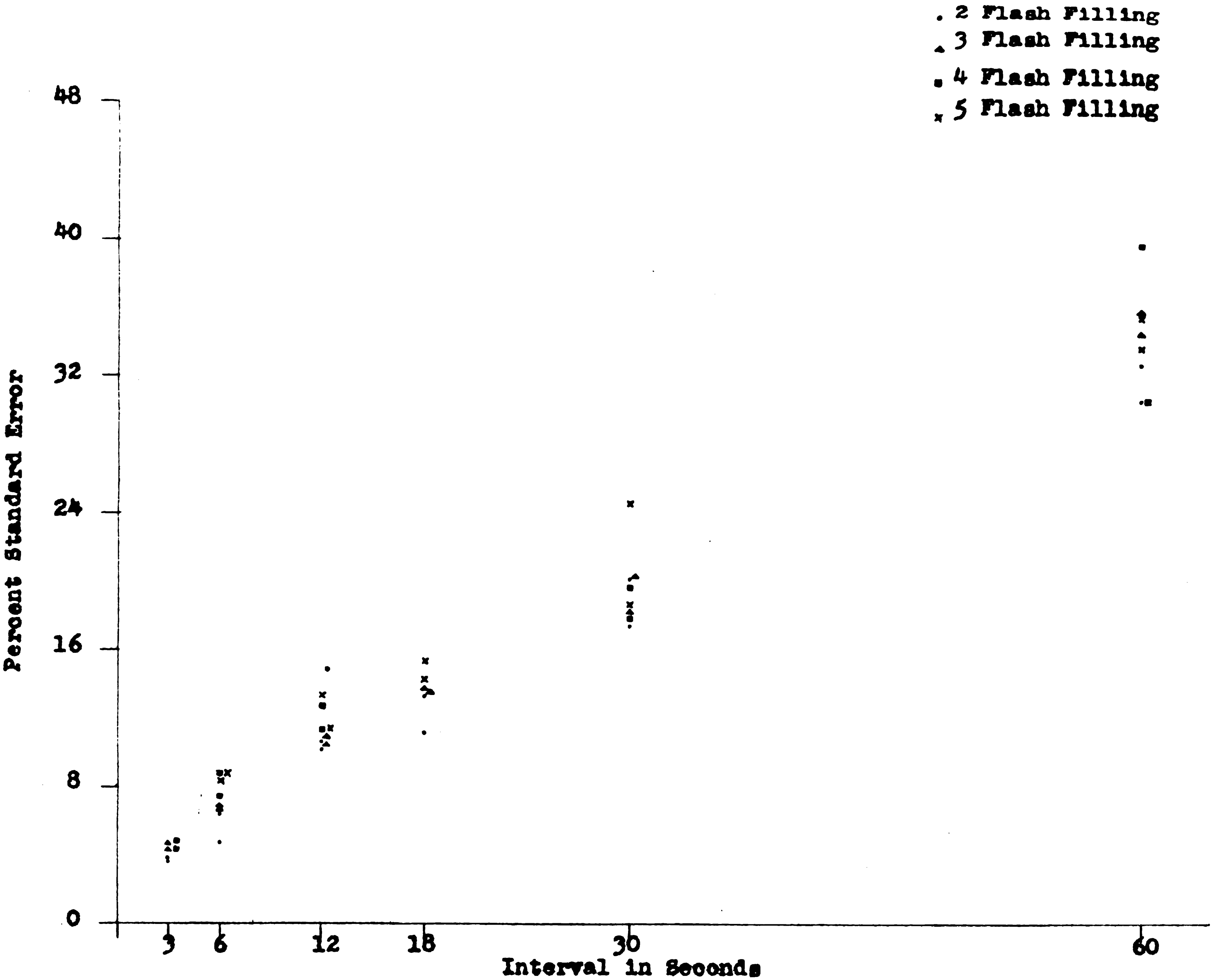

Figure 80. Positive Standard Errors Resulting When Filled Intervals are Compared to Empty Intervals. Various levels of filling and 6 interval lengths were used. Data is from 2 subjects. Each point represents 10 comparisons.

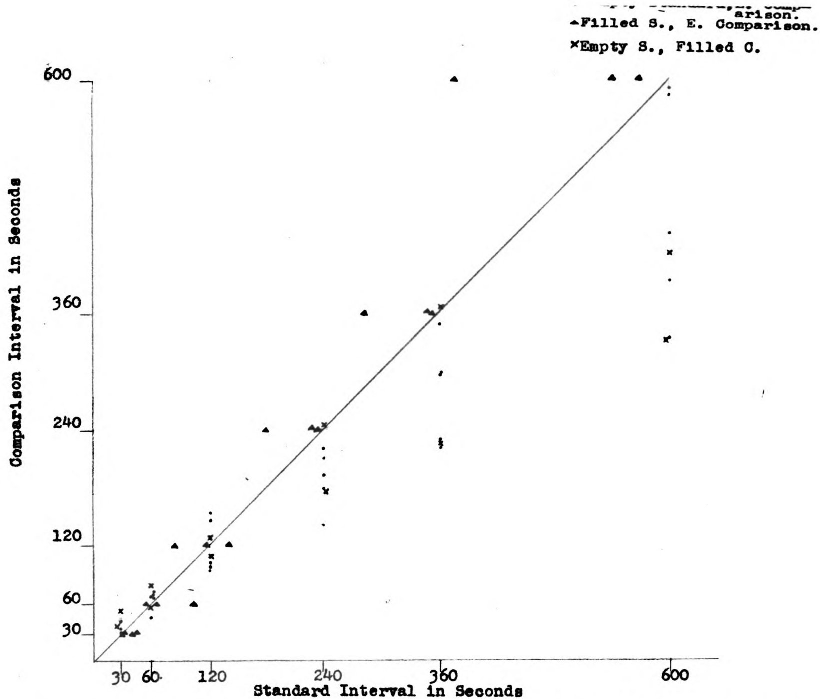

Figure 81 Comparison Interval Necessary to Produce Equality when Standard Intervals of Various Clock Lengths are Used. Each point represents 10 observations. Data is from 3 subjects.

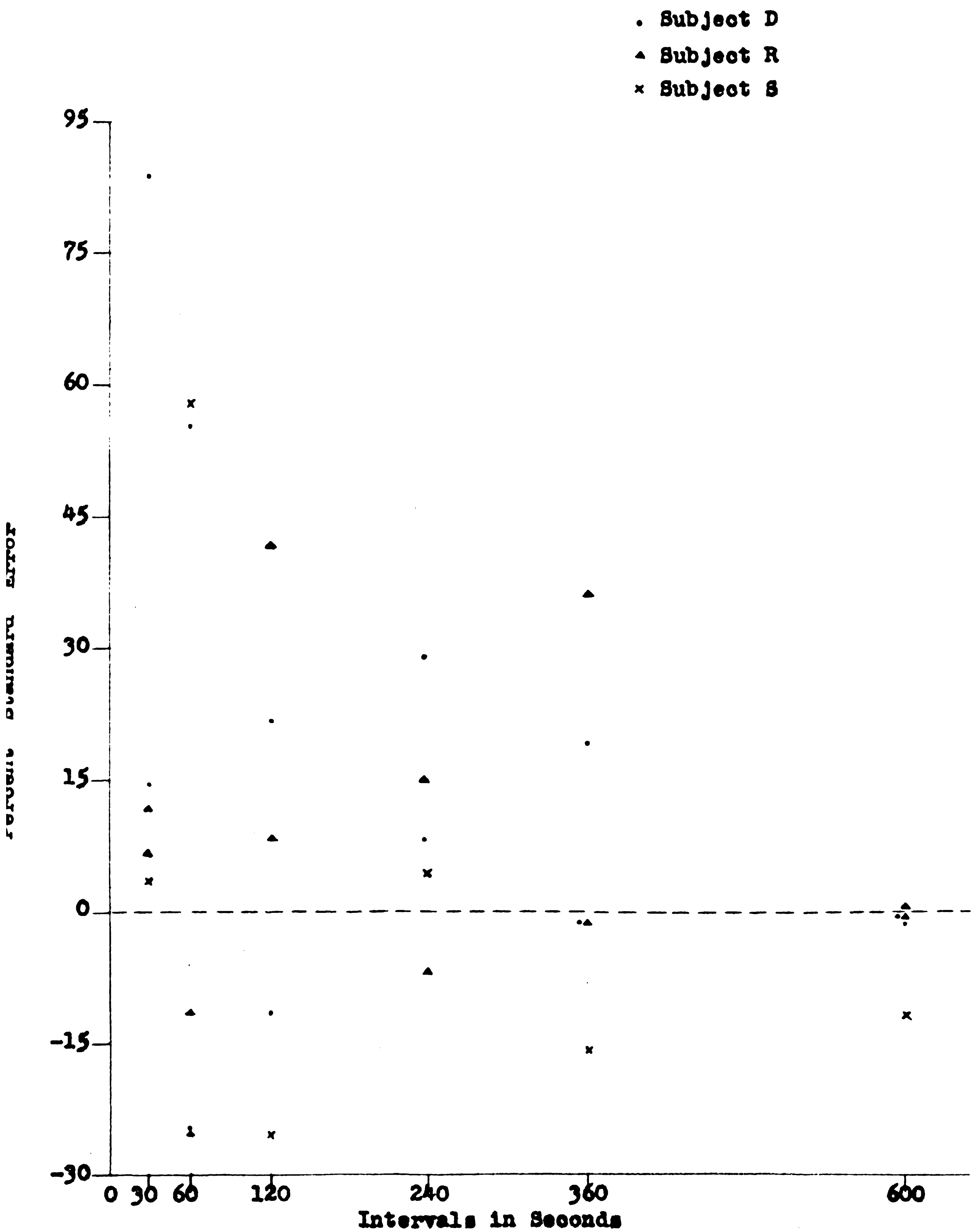

Figure 82. Standard Errors Resulting When Filled Intervals Were Compared to Unfilled and Vice Versa. Six interval lengths were used. Data is from 3 subjects. Each point represents 10 observations.

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