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SUBJECTIVE DURATION AS AFFECTED BY STIMULUS EVENT RATE, RESPONSE COMPLEXITY, AND TASK DURATION

by

Leslie S. Klein

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Abstract

The literature was reviewed with respect to two hypotheses concerning human time perception. The biological clock hypothesis is based on the proposition that subjective duration is dependent on some rhythmical organismic process which acts as an internal clock. The cognitive clock hypothesis is based on the reasoning that the perception of duration is directly dependent on the succession of events. Specific predictions arising from these two hypotheses were examined in Experiment 1, which was concerned with the perception of the duration of intervals in the psychological present. The results of Experiment 1 weakly supported the biological clock theory.

Experiment 2 investigated the perception of the duration of intervals in the psychological past. Two opposing predictions, each based on research reported in the literature, were examined. One set of studies postulated that increased stimulus complexity results in increased subjective duration of past intervals when no overt responses are made to stimuli. Another set of studies postulated that overt responding results in decreased subjective duration with increased task complexity. The results of Experiment 2 neither fully supported nor rejected each prediction. Rather, complex processes seemed to be evident, the nature of which is presently not understood.

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Nature of the Problem

Time has been the subject of philosophical debate for centuries. Psychologically, Man's experience of time has been thought to arise either through the action of some biological mechanism which operates as an internal clock, or as the product of a cognitive process which is dependent on events in the environment. This thesis is an investigation of the effect of certain cognitive variables on the subjective experience of time. Two studies were performed. Experiment 1 was concerned with the perception of intervals in the present, and Experiment 2 investigated the experience of the duration of intervals in the past. Both studies were primarily concerned with the subjective organization of time, rather than with time estimation accuracy.

The literature was treated in two sections. The first consisted of an examination of some research and speculation concerning the role of biological processes in time experience, and cognitive approaches to subjective duration were considered in the second section.

A Preliminary Note on Terminology

Three methods have most often been used in studies of time perception: (*a*) direct estimation method (DEM), in which *Ss* make direct estimates of some interval in hours and/or minutes and/or seconds (which for convenience will henceforth be called real-time); (*b*) production method (PM), in which *Ss* are instructed to produce an interval expressed to them by *E* in real-time units; and (*c*) reproduction method (RM), in which *E* first demonstrates an interval, and then *Ss* reproduce the interval. In the last method, the real-time duration of the interval is usually not mentioned. In general, the interval that is presented to *Ss* is called the standard.

When *Ss* give verbal estimates, or produce, or reproduce an interval that is greater than the standard, then *Ss* have *overestimated* the standard. The converse is when *Ss* *underestimate* the standard. Much of the literature tacitly assumes that there is some internal clock which operates at various rates. Bindra and Waksberg (1956) point out that the above methods and resultant responses have different implications as to the rate of the internal clock. In particular, an overestimation with the DEM implies that the internal clock is faster than the real-time clock, i.e., that the internal clock has many units per real-time clock unit. In the PM, when *Ss* overestimate the standard, the implication is that the internal clock is slower, and has larger units than the real-time clock units. The implications of overestimation in the RM are similar to the PM, the difference being that there is some uncertainty as to the stability of the rate of the internal clock during the presentation of the standard, and during its reproduction.

It should be noted that the DEM is only appropriate for estimating intervals in the past, that the PM is concerned with regulating a current interval based on Ss preconceived notions about the duration in question, and that the RM is concerned with regulating an interval in the present based on the subjective duration of the recently presented standard.

Biological Bases of Time Experience

The role of specific physiological processes in subjective duration is not of major concern in the present investigation. This does not mean, though, that physiological processes are not important. The following review examines some of the speculations and findings associated with a biological clock theory of time estimation.

Briefly, a biological clock theorist would postulate that there is some physiological activity (or set of activities) which supplies the "tick-tock" of an internal clock. Thus, when we want to estimate the duration of an interval, we first define the interval by its boundary events, and then count the number of clock units between them. The total amount, or some transformation of it, is the time for that interval.

The above method of time perception has two logically independent implications: (a) there is some rhythmical physiological activity, and (b) this activity is the basis of time perception. There is ample evidence for the first point, but it is only the second point that is both a necessary and sufficient condition for the biological clock hypothesis. Perhaps the overabundance of evidence for biological rhythms overrides the paucity of evidence for the second point. It is likely that the fundamental identity of mechanical rhythms of clocks and physiological rhythms of organisms, leads to the belief that the presence of physiological rhythms is the sole and sufficient condition for a biological clock. Not only is the notion logically at fault, but, for the most part, it lacks strong experimental support. The existence of physiological rhythms is well recognized (Cloudsley-Thompson, 1966). What is of interest to this thesis is the evidence that these rhythms or one of them is the basis of time experience.

Investigations seeking support for the biological clock theories can be divided into two categories. There are studies which assume the presence of a biological clock and seek a direct correspondence between time estimation and certain physiological rhythms. Then, there are studies which attempt to demonstrate the presence of a biological mechanism where "cognitive" factors can be rulled out.

Pieron (1923) reasoned that since the clock mechanism is a physiological activity, it can be affected by variables which can affect all other physiological functioning. One of these varibles is the temperature of the organism. Pieron's suggestion was supported by Hoagland (1933) and perhaps by Pfaff (1968). Both Hoagland's and Pfaff's conclusions were that as body temperature increased, the internal clock rate increased, resulting in overestimation of standard intervals (with DEM). Conversely, when body temperature is lower, or in Hoagland's case returned to normal, the biological clock ticks at a slower rate, resulting in a tendency toward underestimation. Adam, Rosner, Hosick, and Clark (1971) did not find a relation between body temperature and time estimation, and Lockhart (1967) found an increased clock rate with increases and decreases of ambient temperature. Adam (1971) reported that studies of time estimation and metabolic rate as affected by hyper- or hypothyroid conditions failed to yield conclusive data. The current status of the relation between body temperature and time perception is, therefore, unclear.

Many investigators have tried to establish a relation between subjective duration and alpha rhythm, which when detectable on electroencephalographic (EEG) recordings, exhibits a frequency of about ten cycles per second (hz) (Deutsch and Deutsch, 1966, p. 145). A relation between the two has been found in some studies (Cahoon, 1969; Ross, 1968) but not in others (Adam, et al., 1971; Legg, 1968). The alpha rhythms basis of time perception has been championed by some experimenters who have noted that there is a certain perceptual confusion or fusion of events that take place within approximately 0.10 second intervals (see Harter, 1967 for a comprehensive review). It is thought that the fusion-confusion interval is not just coincidently similar to one alpha cycle, but a result of it. It is believed that there is a psychological unit or moment based on alpha activity during which perception takes place. All processing within one moment is chunked together, and separated from processing in other moments. If indeed alpha rhythm were the basis of time perception, it would be reasonable to expect that the most accurate interval that can be estimated would be about 0.10 seconds. Fraisse (1963) points out that the indifference interval (that duration which is neither consistently under- nor overestimated) is around 0.70 seconds with a wide range, depending on the method that is used.

Extensive work on the relation between alpha rhythm and time experience has been carried out by Holubar (1961). He conditioned human Ss to emit a clear galvanic skin response (GSR) once every 30 seconds. Once this rhythm was established, Ss were subjected to light flicker rates of 5, 7, 10, 14-15 and 20 hz. Holubar demonstrated that such photic driving soon resulted in synchronous alpha activity rates. For four Ss in which the flicker did not wipe out the GSR, the resultant response intervals were 26, 14, 27.5, 15.5, and 23 seconds, respectively. While multiples of 10 hz (i.e., 5, 10, and 20 hz) had little effect on the conditioned interval, both the 7 and the 14-15 hz flicker reduced the conditioned interval to about 15 seconds. Although the results indicate that alpha rhythm may be involved in time experience, the nature of the relation is not clear. Holubar did not offer an explanation as to why there was not a monotonic relation between alpha rate and response intervals, as would be expected. The results suggest that not only alpha rhythm but also the process of transforming the cycles into time segments is affected by flicker rate. Perhaps the best conclusion is that of Legg (1968): "Certainly the simple model in which cycles of the alpha rhythm act as ticks for a subjective clock may be discarded (p. 49)."

Many other physiological processes have been investigated. Schaeffer and Gilliland (1938) found that there was no relation between subjective duration and pulse rate, heart rate, heart work, blood pressure, breathing rate, or lung work. Similar findings were obtained by Adam, et al. (1971) in a study in which Ss were anesthetized. The one effect that was evident was that the anesthesia resulted in overestimation (by the PM), thus suggesting that the rate of the internal clock had decelerated. The analysis presented in the preliminary note suggests that had the DEM been used, the Ss would have underestimated the standard. These results of the effects of anesthetics are directly opposite to the findings of studies in which administered drugs accelerated central biological functioning (Cohen, 1967; Fraisse, 1963; Ornstein, 1969). LSD-25, marijuana (Watts, 1970), and amphetamines (Goldstone, Boardman, and Lhamon, 1958) tend to increase the subjective duration of the present, suggesting that some internal clock was ticking at a faster rate than real-time clocks. Cohen (1967) noted that under such drug conditions, Ss' overt activity rates may be accelerated, suggesting that input-output function rates may be inversely related to subjective duration.

Time experience is related to some physiological process(es), but it is not clear that this process is rhythmical or cyclic in nature and therefore is not supportive of biological clock theories.

Heart beat is perhaps the most obvious physiological rhythm and is often considered as the basis of the biological clock. Alterations of heart rate in the absence of external reference to real-time should, therefore produce systematic changes in time estimation. Most investigators have computed correlations between heart rate and time estimation, and as a whole, these correlations have been negligable. Furthermore, correlation does not imply causation. Ochberg and Triester (1970) systematically controlled heart rate in two groups. The Ss in both groups were adult males who had undergone heart surgery, and were otherwise similar except for one variable, the presence or absence of a cardiac pacemaker. Whereas the non-pacemaker group had more or less usual responses to exertion, the pacemaker group had a steady heart rate under all conditions. Ochberg and Triester found that before and after exertion there was no difference in the subjective duration of the two groups.

In summary, the studies which have assumed the presence of a biological clock have failed to define the specific physiological activity, or its location.

The second set of studies is less concerned with the locus of the clock as with establishing its presence. Good examples of this group are found in experiments of time processes in sleep.

There is evidence that some people can accurately awake at any predetermined time, especially if the designated waking time is close to the Ss usual waking time (Fraisse, 1963). Zung and Wilson (1971) found that out of 33 awakenings, 14 were within ten minutes of various predetermined times. They also found that this accuracy was independent of the stage of sleep (as characterized by EEG recordings) just prior to awakening. The results suggest that for this type of task (which can be called long-term PM) there may be a fairly accurate timing process which is not situated in the cortex, the area which most influences EEG records (Deutsch and Deutsch, 1966, p.145).

Examining another type of task involving sleeping Ss, different results are obtained. When Ss are asked to estimate the durations of stages of sleep just after termination of a stage, the estimate is influenced by the kind of cortical activity during that stage (Carlson, Goodenough, and Feinberg, 1968). The findings of Zung and Wilson (1971) and Carlson et al. (1968) are difficult to reconcile, even though they both support the notion that certain physiological processes are involved in time estimation. The main difference between the studies is that the long-term PM of Zung and Wilson was based on Ss preconceived notions about the duration of the production interval, whereas the DEM in Carlson et al. depended on ongoing neural activity during the test interval. Since cortical activity is the major contributor to EEG recordings, the above findings suggest that the PM and the DEM are based on different neural mechanisms, with the former relatively immune to ongoing cortical activity.

In summary, studies of temperature variation, alpha rhythm, drugs, temporal conditioning, and timing in sleep have failed to define or locate a rhythmical physiological activity that can be called an internal clock.

Cognitive Basis of Time Experience

Before discussing cognitive as distinct from physiological functioning in time experience, it should be mentioned that what is meant is not that cognition occurs without a physiological substrate, but that the level of organization that is being considered is different in nature. A good analogy is the operating computer, which consists of two systems. One is tangible - the actual physical components of the computer. The other is non-tangible - the information flowing through the physical structure. Physiological functioning is comparable to the former, cognitive functioning is comparable to the latter.

Loehlin (1959) reported that the cognitive factors that influence time experience are: (a) interest versus boredom, (b) filled versus empty intervals, (c) repetitions of an activity, and (d) activity versus passivity. These four factors can further be condensed into: (a)environmental stimuli, and (b) responses to these stimuli.

Perhaps of all questions concerning the experience of time, that of filled versus empty intervals has been the most extensively investigated. Early work on this question supported the hypothesis that filled (interesting, active) intervals appear to pass more quickly than empty (dull, passive) intervals (Dobson, 1954; Gulliksen, 1927; Swift and McGeogh, 1925). These judgements were generally given after the interval by the DEM. If RM or PM were to be used, Adam (1971) maintains that, on the basis of the inverse relation between the DEM and the PM (Clausen, 1950; Bindra and Waksberg, 1956; Carlson and Feinberg, 1970), the shorter the experienced duration, the longer the subsequent production. That is, the busier S is during the production interval, the longer it will be, as measured in real-time units. (For the S, the apparent duration of the production interval would be equal to the standard). An alternate prediction may be that the busier a S is in the production interval, the shorter it will be, as measured in real-time units. Adam's prediction is based on the reasoning that longer productions would be expected in a filled interval " ... because activity diverts attention from the hypothesized clock (p. 43)." The latter prediction is derived from the reasoning that time experience is directly related to the succession of events, a line of thought expressed by the British Empiricists (Boring, 1942).

It is very difficult to define an empty interval. Even though Ss may not be exhibiting any overt activity, mental activity is surely going on. It is a mistake of many investigators to have their Ss delimit a period of time during which the activity of the Ss is not being controlled. Only when different degrees of the same activity are being systematically varied, can statements be reliably made about the effects of filled versus relatively empty intervals.

The filled versus empty interval factor combined with considerations of intervals in the past or present results in what Cohen (1967) has called the "idle active paradox." While currently engaged in a task, if S is active, time will appear to pass more quickly in comparison to an equal interval spent in doing nothing. However, when the intervals are in the past, a transformation takes place so that the filled interval seemed to have taken longer than the empty one. James (1890) maintains that since the filled interval by definition was more eventful than the empty one, there was more to remember from the filled interval than the empty one. Therefore, the filled interval seems longer. This explanation is the forerunner of the more recent "storage size" hypothesis of Ornstein (1969). This is not though, an explanation of the different perceptions of filled and empty intervals in the present, only in the past.

The storage size metaphor (Ornstein, 1969), which is an information processing approach to the experience of time, states that the more information that is stored, the larger the amount of space taken up by the event. According to Ornstein, the perceived duration of past events is directly related to the retrieved storage size of the event. If the space is large, the duration will seem to be great; if the space is small, the duration will seem to be short.

This elaboration of James' (1890) hypothesis has many implications, some of which have been tested by Ornstein. Ornstein's most conclusive study involved the manipulation of storage size after the event had been stored (and thereby eliminated any peripheral input effects). First, he presented an ambiguous figure to all Ss. Then, he informed one group that the drawing could be decoded (by remembering that it was the word "man" inversed and superimposed on itself). Upon asking Ss to compare the viewing time of the drawing with that of the standard interval (presented auditorally), the group that had been informed of the code judged the viewing time to be shorter than those who were uninformed. Ornstein argued that the code resulted in diminishing the storage size for the drawing in the informed group, resulting in shorter perceived durations. In order to check his maipulations, Ornstein asked Ss to describe the drawing. He found that the length of the description by the uninformed group to be greater than that of the informed group. Furthermore, a third group which had been given the drawing in the decoded form described it in the fewest words (and reported the shortest durations). Ornstein took the number of words to be a direct measure of the storage size for the three groups.

Ornstein (1969) presented a convincing case that human time experience is the result of active construction by cognitive processing. However, the storage size hypothesis does not explain the experience of time during current intervals, where the inverse relation holds. As well, the use of the term "storage size" is vague and can generate many unanswered questions. (For example: What is the metric unit of the storage space and how is it transformed into subjective duration?). Another drawback to Ornstein's approach is that there is a lack of precise relations between stimuli and subjective duration.

Nonetheless, there is other evidence that stimulus complexity and subjective duration are interrelated in a way that supports Ornstein's hypothesis. When Ss are presented stimuli of varying complexity, the more complex the stimulus, the longer Ss will examine it (Gaeschk, Kintz, and Thompson, 1968; Zelkind and Bachuber, 1970). Denis (1971) found that the more disturbances in an ordered message, the greater the overestimation of the duration of the message. This was found only when the order of the message was important. Thus, upsetting the predictability of the message, thereby increasing the amount of contained information, resulted in an increase in subjective duration. Similar results were obtained when the presentation rates of nonsense syllables and sentences were manipulated (Friel and Lhamon, 1965).

However, a study by Vroon (1970) has cast some doubt on the extensibility of Ornstein's findings. Vroon duplicated the essential features of Ornstein's study and obtained similar results. However, when Vroon had Ss respond to the stimuli he had presented, filled intervals were judged shorter than relatively empty ones of equal real-time duration. Thus, the amount of stored information may not be the sole determinant of the apparent duration of intervals in the past.

Other studies have reported that increased complexity resulted in decreased subjective duration. Hawkins and Meyer (1965) manipulated the total amount of information in a task by (a)giving Ss nothing to do, (b) giving Ss a task but not allowing them to complete it, and (c) giving Ss a task and allowing them to complete it. They found that the empty interval was greatly overestimated, the unfinished task interval was underestimated, and the completed task was greatly underestimated. Burnside (1971) varied the amount of complexity of a task that lasted from 10 to 20 seconds on different trials. The Ss task was to reproduce the apparent duration of the task interval after the task had been completed. Burnside found that as the complexity of the task increased, the reproduction intervals decreased. He also found that the task output was more or less constant for all conditions. Thus, output may not be an indicant of storage size, as Ornstein (1969) would have it, and may not be related to subjective duration. The inverse relation between complexity and the subjective duration of intervals in the past was also obtained by Smith (1969) in an analogy-solving task.

If Ss respond to stimuli (aside from reporting duration) then increased complexity or activity results in decreased subjective duration (Burnside, 1971; Hawkins and Meyers, 1965; Smith, 1969; Vroon, 1970). However, if Ss merely examine a stimulus, then increased complexity results in increased subjective duration (Denis, 1971; Friel and Lhamon, 1965; Ornstein, 1969). This apparently clear division is, however, obscurred by the results of another study. Warm and McCray (1969) found that when high and low frequency words were tachistoscopically presented for equal intervals, the high frequency (low information) words were judged as being exposed for longer durations than low frequency words, especially when long words were presented. (In general, it can be considered that the degree of complexity is directly related to the amount of information). Warm and McCray's design was of the no-response type, but the results were similar to the response studies. Clearer definitions of the stimui and responses are necessary before the validity of the active passive factor can be established.

It is obvious that cognitive varibles and subjective duration are related, but the nature of the relation is ambiguous. The ambiguity of the findings stem from the lack of clear definitions of filled and empty intervals, stimulus complexity, responses, and from widely diverse research methodologies.

Methodologies

Most studies of time perception have used repeated measures designs in which each S is administered many trials in one condition and/or many conditions. The present studies used different Ss in each experiment, and for only one trial and treatment combination. The reasons for this are outlined below.

Firstly, Ss' accuracy in estimating real-time was not of interest in the present investigation. As Ornstein (1969) noted, if Ss know that the duration of events is important they will "... attempt to be as 'accurate' or consistent as possible and to count regularly to themselves or to tap their feet or to do something to nullify the whole experimental manipulation (p. 52)." If accuracy was of primary interest, Ss would have been told that the study concerned time. The present studies were interested in variables that may affect time experience in everyday life, where the potential of the consciousness of the duration of an event is always present, not the actual task of estimating time. To this end, in the present studies the standard interval was given to Ss before the time aspect of the study was explained. Thus, the set of standard interval and test interval could only be administered once.

A confusing array of results have come from studies in which repeated trials have been used. In any repeated trials design, Ss must estimate or produce or reproduce the second and subsequent intervals after doing so previously. If Ss do not get any feedback or interpolated standards, second and subsequent intervals are likely to be increasingly overestimated (Falk and Bindra, 1954; Shectman, 1970; Stott, 1935; Woodrow, 1935; Woodworth and Schlosberg, 1954). When non-directional feedback is given, reproduction intervals become shortened (McConchie, 1970). The former effect increases with the number of trials to the point where Maloney and Callaway (1971) warn that tight control of long intervals previous to a test interval is warranted. For the PM, there is evidence that after repeated trials Ss do not successively increase their estimates, but eventually reach an approximation that is a slight overestimation of the standard (Emley, Shuster, and Lucchessi, 1968). If interpolated standards of directional feedback is given, Ss become more accurate in their estimates (McConchie, 1970; Hoyer and Jones, 1970; Hoyer, Jones, White, and Maconacky, 1970). However, when anchors are presented between trials of different methods, the differences between methods mentioned in the Preliminary Note are not eliminated (McConchie and Rutschmann, 1971). Finally, after an investigation of the relations between methods, Carlson and Feinberg (1970) concluded that Ss internal clock rates are not constant from trial to trial.

The above results do not present answers to the following questions, each one of which suggests a research design. (1) What effect does reproducing a standard in one trial have on the perception of a standard in the next trial? (2) What is the relation between repeated estimates of one standard, without feedback, and various activities (E's manipulations) during the reproduction intervals? (3) What is the effect of lengthening retention on the memory representation of the standard interval? Each of these questions is interesting in its own right, but would have made interpretation of results more difficult in the present studies if repeated trials had been used. By using each S only once, these questions were avoided, and any results of the studies were not obscured by them.

Statement of the Problem

Two major themes have been discussed in the literature of subjective duration. One of these themes has been the perception of the duration of intervals in the psychological past, and the other theme has been the perception of the duration of intervals in the psychological present. One purpose of the present set of studies was to make an overall examination of both themes in terms of common independent variables. As discussed in the Methodologies section, a wide variety of results have been obtained from many different studies which contained different independent variables. The ideal solution to this problem would be to have one study in which the effects of one set of independent variables would be examined on both the psychological past and present for each subject. However, as considered in the previous section, the resultant problems when examining an individual subject more than once, and the necessity of using different measuring techniques (see Preliminary Note), renders this ideal solution highly impractical.

Thus, in the present investigation, two separate experiments incorporating the same two independent variables were done. Each experiment examined different subjects only once with the appropriate measuring technique. It should be noted that the two experiments were logically independent, and their sequential order was arbitrary; i.e., the second study was not dependent upon the outcome of the first.

One particular question that was examined in the present thesis was whether the subjective duration of a current interval is directly related to the sequence of events, or is related to the degree that attention is diverted from an hypothesized internal clock. This question was examined in Experiment 1.

Experiment 2 was primarily concerned with the subjective duration of an interval in the past. This second study examined the different effects of overt and covert responding to stimuli. In both studies the filled interval versus empty interval variable was represented by systematic manipulation of the rates of stimulus events. As well, both studies examined the effects of various amounts of response complexity on subjective duration.

Design

The discussion in the Methodologies section considered the effects of informing Ss before certain critical intervals that the durations of such intervals were important. For the aforementioned reasons, Ss in the present experiments were not informed as to the real-time durations of the critical intervals and the experimental sessions took place in the absence of clocks and watches.

Two studies were performed, both run as completely randomized designs. Experiment 1 investigated the effects of response complexity and event rate on the perception of the duration of a current interval, and Experiment 2 was concerned with the effects of response complexity, event rate, and real-time duration on the perception of the duration of an interval in the past.

Both studies had the following independent variables in common: Response complexity was determined by the type of response to each stimulus event. The three levels of response complexity were (a) No overt response to each stimulus (0-R); (b) Simple response to each stimulus (1-R), in which Ss pushed a lever in one direction whenever they saw a stimulus; and (c) Choice response to each stimulus (2-R), in which Ss pushed a lever in one of two directions depending on which one of two stimuli was present. Event rate was determined by the number of stimulus events per unit real-time. The four event rates were 20, 40, 60, and 80 stimuli per minute.

Experiment 2 had one other independent variable, the Duration of the task, which was determined by the duration of the stimulus sequence. The three durations were 30, 60, and 90 seconds. The independent variables in each study were completely crossed.

The dependent variable in Experiment 1 was the real-time duration of each Ss' reproduction interval of the duration of a standard tone series. There were two dependent variables in Experiment 2. Ratio 1, one of the dependent variables, consisted of the apparent duration of the stimulus sequence relative to the duration of a tone series, without the use of real-time units. Ratio 2, the other dependent variable, consisted of the same comparison with the use of real-time units.

More specific details about the above variables are presented in the appropriate Method sections to follow. The overall procedure of both studies can be divided into five phases:

Phase 1. Expt. 1 - Ss were instructed in the use of the response apparatus.

Expt. 2 - Ss were instructed in the use of the response apparatus.

Phase 2. Expt. 1 - The standard 30 second tone was presented.

Expt. 2 - The standard 30 second tone was presented.

Phase 3. Expt. 1 - Ss were instructed that the duration of the tone series was important.

Expt. 2 - Ss were not instructed about the tone series.

Phase 4. Expt. 1 - Ss responded to visual stimulus events while keeping track of passing time, and stopped a clock when they thought that the tone interval had been equalled.

Expt. 2 - Ss responded to visual stimuli for the length of time determined by the particular duration condition.

Phase 5. Expt. 1 - End of experiment.

Expt. 2 - Ss asked to compare the amount of time they had spent responding to the visual stimuli and the duration of the tone interval. (Two different measures were taken).

Experiment One

Method

Stimulus Construction

Four sets of stimuli were constructed, each representing one of the 20, 40, 60, and 80 per minute event rates. Each set was a series of either red or green colors exposed on 8mm movie film and projected at 18 frames per second. In all sets, each color was exposed for 9 frames resulting in 0.5 second when projected. The sequence of colors was random with the constraint that no color appear more than three times in a row. The segments between colors were black and were 45, 18, and 9 frames long for the 20, 40, and 60 per minute event rates, respectively. The four or five black frames between colors in the 80 per minute event rate film sequence were randomly assigned to intervals. One other film sequence was prepared to be used in the instructions.

The standard interval was 30 seconds long, and consisted of random duration and frequency pure tones generated by a Hewlitt Packard wide range oscillator and recorded by a Sony TC-252 taperecorder.

Apparatus

The films were projected by a Kodak "Ektagraphic Super-8" projector (Model # MFS-8). This machine is designed to allow for remote control starting of film sequences.

Instructions, tone series, and white noise were taperecorded and presented through earphones to Ss. The white noise was presented throughout the experiment except during the instructions and the tone series. An event recorder and a clock were used to monitor each S's responses and the durations of the reproduction intervals.

All of the above apparatus was in one room. The Ss' response apparatus and the projection screen were in an adjoining room connected by tubes. The Ss' room was equiped with three identical sets of response apparatus so that three Ss could be run at once. The Ss were visually separated by a large panel, and acoustically separated by white noise. In front of each S there was a panel at approximately 30 degrees from the horizontal. In the center of the panel there was a silent switch to stop one of the clocks in the control room, and at the top of the panel there was a large upright handle which could be moved from side to side, and was connected to the event recorder. The panel, about one foot square, was vertically divided into red and green halves for the 2-R condition, and into black and white halves (to minimize confusion with the color sequences) for the 1-R and 0-R conditions.

Subjects

The number of Ss was determined on the basis of (a) the desire for the statistical tests to have a high power efficiency since there is a lack of consistent findings in the literature, and the exploratory nature of the present research, and (b) the E's ability to run three Ss at once. For nine Ss per cell, power > .995 to detect differences of 0.5 standard deviations about a theoretical mean (Kirk, 1968). In order to reduce within cell variability, and because of the larger proportion of females to males in the University of Manitoba subject pool, only female Ss were recruited.

One hundred and twenty six females were randomly drawn from the subject pool. They took part in the experiment for partial course credit. The order of treatment combinations was partially randomized, and Ss were assigned to conditions in the order of arrival. Complete randomization of conditions was not possible because the changes of panel colors for the different conditions (see above) required extra time between the 2-R and the other conditions.

Data from 18 Ss who wore watches on their preferred hand (see below) or did not understand the instructions, were not analyzed.

Procedure

Subjects were led into the experimental room. Each S was asked which was their preferred hand, and then a large, elbow-length mitt was placed on the non-preferred hand. Subjects were told that the mitt was a reminder not to use their non-preferred hand to operate the controls. After Ss were seated, they were told that all instructions were to be given through the earphones, which were then placed on Ss. Then E left the room, entered the control room, and started the equipment.

All instructions were preceded by 20 seconds of white noise. In the first part of the instructions, Ss were told how to operate the handle. Subjects in the 0-R group were told to move the handle to the white side of the panel when the color sequence began, and to hold it there until the sequence ended. Subjects in this group were also told to try to detect the presence of an orange color, and they would be asked at the end of the experiment if they had seen it. The latter instruction was designed to insure that Ss attended to the color sequence. Subjects in the 1-R condition were instructed to move the handle to the white side of the panel each time they saw a color, and the Ss in the 2-R condition were told to move the handle toward the red side of the panel when they saw a red color, and toward the green side of the panel when they saw a green color. Subjects were then presented with a practice sequence containing four colors.

After completing the practice color sequence, Ss were instructed to " ... listen carefully to the following tone series because I am going to ask you questions about it later." After the presentation of the tone series, Ss were informed that the switch in the center of the panel stopped a clock. They were then asked to reproduce an interval equal to the duration of the tone series while operating the handle in response to the colors on the screen. Then, the color sequence and the clocks were simultaneously started by E. All Ss continued operating the handle throughout the color sequence (which lasted three minutes) except to pull the switch.

Results

The reproduction intervals were analyzed with a 3 X 4 fixed effects analysis of variance for the main effects of response type (RES) and stimulus event rate (RAT) respectively, and the interaction of the main effects. Only the interaction (RES X RAT) proved significant (see Table 1 for means and standard deviations, and Table 2 for the summary of the analysis). A graph of the interaction is presented in Figure 1. Further insight into the data was gained by doing tests of simple main effects within the RES X RAT interaction. As shown in Table 3, the test for RES at the four levels of RAT indicated that there was essentially no difference between responses at the 20, 40, and 60 per minute event rates, but that there was a significant difference at the 80 per minute event rate. Tukey's HSD test for pairwise comparisons (Kirk, 1968) showed that the differences between the means for the 0-R and 1-R conditions, and the 1-R and 2-R conditions were significant (see Table 4). The means for the reproduction intervals in the 80 per minute event rate were $\bar{X}_{0-R} = 31.75$ sec, $\bar{X}_{1-R} = 52.22$ sec, $\bar{X}_{2-R} = 73.71$ sec, and imply that when <u>S</u>s were responding at a very fast rate, increases in the complexity of each response resulted in increases in the real-time duration of the reproduction interval.

The tests for simple main effects of RAT at the three levels of RES (see Table 5) showed that only the choice response (2-R) varied significantly across rates ($p < .01$). A closer examination of the 2-R response function revealed the presence of quadratic and cubic trend components ($p < .05$, see Table 6). Given the linear increases in event rates, the presence of these trend components was quite unexpected, and is considered more closely in the Discussion section.

Table 1

Cell Means (and Standard Deviations) for Experiment One in Seconds

		Response Type		
		0-R	1-R	2-R
	20	58.04(21.94)	58.41(26.88)	45.25(25.26)
Event	40	27.07(13.03)	48.02(21.14)	47.14(20.50)
Rate	60	41.19(26.77)	51.26(28.15)	31.58(16.05)
	80	31.75(16.69)	62.22(35.03)	73.71(37.69)

Table 2

Analysis of Variance for Experiment One

Source	df	SS	MS	F
Response type (RES)	2	3305.9766	1652.9878	2.62
Event Rate (RAT)	3	4037.5391	1345.8462	2.13
RES X RAT	6	9899.5117	1649.9185	2.61
Within Cells	96	60643.9570	631.7078	
Total	107	77886.8125		

$_{.05}F(2,96) = 3.09$

$_{.05}F(3,96) = 2.70$

$_{.05}F(6,96) = 2.19$

$_{.01}F(6,96) = 2.99$

Table 3

Analysis of Simple Main Effects of RES in Experiment One

Source	df	SS	MS	F
RES at RAT_{20}	2	1010.72	505.36	0.80
RES at RAT_{40}	2	2527.44	1263.72	2.00
RES at RAT_{60}	2	1743.18	871.59	1.38
RES at RAT_{80}	2	7924.46	3962.23	6.27
Within cell	96	60643.96	631.71	

$_{.05}F(2,96) = 3.09$

$_{.01}F(2,96) = 4.83$

Table 4

Tukey's HSD Test for Differences Between Means Within the 80 Per Minute Event Rate in Experiment One

Comparison	Obtained $q(3,98)$
(2-R) - (1-R)	5.13
(1-R) - (0-R)	4.89

$.005q(3,60) = 4.625$; $.005q(3,120) = 4.523$

$.001q(3,60) = 5.365$; $.001q(3,120) = 5.211$

Table 5

Analysis of Simple Main Effects of RAT in Experiment One

Source	df	SS	MS	F
RAT at RES_{0-R}	3	5050.39	1683.46	2.67
RAT at RES_{1-R}	3	509.51	169.84	0.27
RAT at RES_{2-R}	3	8377.77	2792.59	4.42
Within cell	96	60643.96	631.71	

$.05F(3,91) = 2.69$

$.01F(3.96) = 3.98$

Table 6

Summary of Trend Analysis of 2-R Response Function in Experiment One

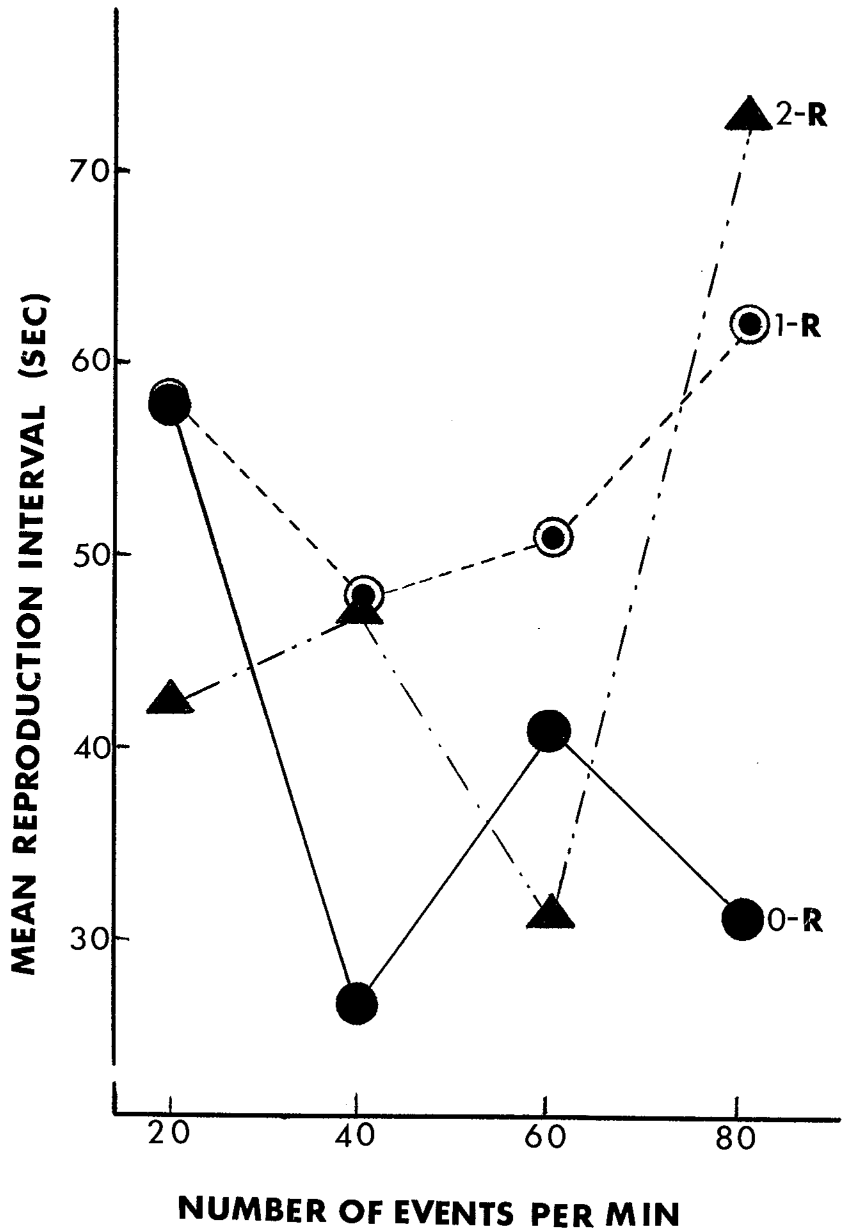
Source	df	SS	MS	F
2-R: linsear trend	1	2192.0337	2192.0337	3.47
quadratic trend	1	3643.3296	3643.3296	5.76
cubic trend	1	2540.7090	2540.7090	4.02
Within cell	96	60643.96	631.71	

$_{.05}F(1,96) = 3.93$

$_{.01}F(1,96) = 6.90$

Fig. 1

Response Type as a Function of Mean Reproduction Interval and Event Rate



Discussion

Experiment 1 examined how Ss' perceptions of the duration of a current interval were affected by the complexity of each response to each stimulus in a series, and the rate of the stimuli in the series. The analysis of the data disclosed two noteworthy findings. Firstly, within the fastest (80 per minute) event rate, as the complexity of each response increased (0-R - no evert response; 1-R - simple overt response; 2-R - choice overt response) the durations of the reproduction intervals increased. This finding supports the biological clock hypothesis which states that increased activity or complexity acts to divert attention from the internal clock, causing Ss to miss ticks and thereby produce longer intervals. The cognitive clock hypothesis would predict that increased activity would result in decreased production intervals because the perception of time is directly related to the succession of events - the greater the complexity the shorter the apparent duration. Thus, the cognitive clock hypothesis was not supported. However, this conclusion must be considered with a great deal of caution, since no systematic relation existed between response types at the other event rates.

The other noteworthy finding was the shape of the 2-R response function across increasing stimulus rates (see Fig. 1). The presence of quadratic and cubic trend components in this function tends to suggest that other unaccounted factors were in operation.

There were peculiarities of the Ss' responses to the color sequences in the 2-R response condition at the 80 per minute event rate. Casual inspection of the records of Ss responses to the colors in all other treatment combinations shows that the responses were consistent and presumably, accurate. (The main purpose of the event recorder was to monitor Ss' responses and thereby make certain that the instructions had been understood. The records were not clear enough to allow for precise analysis). However, the records of the Ss in the 2-R X 80 per minute treatment combination shows that responses were not made to each stimulus event and, presumably, the responses were to some extent incorrect. This finding was not unexpected since Vroon (1970) has reported that the highest event rate for consistency and accuracy for choice responses is 75 events per minute. Subjects in this condition could be described as having experienced an information input rate which exceeded processing channel capacity. In terms of the framework of the present study, this excess resulted in the greatest loss in the ability to keep track of ongoing time.

The best conclusion, then, would be to reserve judgement as to the effects of response complexity and event rate on the perception of intervals in the present. Implications about further research, however, are worth considering.

The main task of subsequent research would be to first isolate and then control the variable(s) that may have been present but were not controlled in the present study. The task that each S was engaged in can be broken down into two components: (a) responding to the colors on the screen, and (b) keeping track of ongoing time. The difference in the characteristics and the demands of these sub-tasks was partially reflected in the difficulty in writing a set of instructions that would be understood by most Ss. The execution of such a dual task requires

Ss to divide attention between the two components (as expected). However, different Ss may have placed different weights on the relative importance of each sub-task. Thus, a large part of the error variability may be attributable to different attention switching characteristics of the Ss. One way to control this variation might be to introduce another independent variable the effect of which would be to establish and specifically advise Ss as to the relative importance of each sub-task. For example, in one set of instructions Ss would be told that it is very important to perform the color response task well, another set of instructions would tell Ss that it is important to estimate the duration of the tone series accurately, and a third set of instructions would advise Ss to give equal importance to each sub-task. On the assumption that Ss would attend most often to the more important task, it would then be possible to examine the effects of different attention switching characteristics in different conditions.

Experiment Two

Method

Stimuli and Apparatus

All stimuli and equipment were the same as used in Experiment 1 except for the clocks and the switches, which were removed from the centers of the panels.

Subjects

It was originally intended to use the same sex (female) and number of Ss per cell (nine) as in Experiment 1. However, difficulties in obtaining the required 324 female Ss led E to recruit both male and female Ss. A sufficient number of females, nonetheless, eventually signed up to fullfill the original intentions. Thus, data was gathered from 324 females evenly distributed among treatment combinations, and 110 males unevenly distributed among treatment combinations. The data from the males was considered supplementary in nature since (a) no logical comparisons could be made with the results of Experiment 1 in which only females were used, and (b) the uneven distribution of males necessitated an unweighted means analysis, which, for reasons considered later, adversely affected interpretation of the anlysis.

The data from an additional 28 females and 8 males were not analyzed because they had either worn watches on their preferred hand or did not understand the instructions.

Procedure

The procedure was identical to that of Experiment 1 except (a) Ss did not control the duration of intervals, (b) Ss were informed of the time aspect of the study only after the presentation of the color sequence, and (c) the duration of the color sequence (i.e., the task) was determined by the particular duration condition (30, 60, or 90 seconds) and was controlled by E.

After completing the task, Ss received a questionnaire in which they were presented with two lines, and were instructed that the top line (5cm) represented the duration of the tone series, and that they were to mark off on the bottom line (22cm) what they thought was the relative duration of the task. After completing the above question, it was removed by E, and Ss were given another questionnaire in which they were asked to state the apparent duration of the tone series and the apparent duration of the color sequence in minutes and seconds.

Results

Females Only - Ratio 1

Ratio 1, one of the dependent measures, was formed by dividing the measured length of the marked-off line, representing the subjective duration of the color sequence, by the length of the line representing the duration of the tone series. Thus, Ratio 1 made no reference to real-time units.

A three-way fixed effects analysis of variance was used to examine the effects of the type of response (RES), stimulus event rate (RAT), and task duration (DUR). The results of the anlysis are presented in Table 7.

The significant three-way interaction (RES X RAT X DUR, $p < .001$) indicated that complex processes were involved when Ss estimated the subjective duration of intervals in the past. In order to get more insight into the data, the RES X RAT interactions for each of the three levels of DUR were isolated (see Fig. 2). Three tests of simple interaction effects were made, one for each of the RES X RAT interactions. To maintain the probability of a Type 1 error at .05, Dunn's procedure (Kirk, 1968) of dividing alpha by the number of tests resulted in an alpha of .0167. The means and standard deviations associated with the above treatment combinations are shown in Table 8, and the results of the tests of simple interaction effects are presented in Table 9. Only the RES X RAT interaction at the 90 second duration condition proved significant. The response functions for this interaction can be seen in the right hand panel of Figure 2.

In order to more clearly isolate the components of variation within this interaction, tests of differences in linear, quadratic, and cubic trends between response types across event rates showed that a significant proportion of the variation was due to differences in cubic trends ($p < .0005$, see Table 10). Tests for the presence of linear, quadratic, and cubic trend components within each response function were performed (see Table 11). The presence of cubic trends was detected in all three response functions. Whereas the functions for the 0-R and 2-R response types varied in the same direction across event rates, the 1-R response function varied in the opposite direction. These similarities and differences are considered in detail in the Discussion.

The significant main effects of RES ($p < .001$) suggests that as the complexity of each response increased, the subjective duration of the task decreased, as reflected in changes in the mean ratios ($\bar{X}_{0\text{-R}} = 1.51$; $\bar{X}_{1\text{-R}} = 1.38$; $\bar{X}_{2\text{-R}} = 1.20$). This finding is contrary to the storage size hypothesis (Ornstein, 1969) and supports the findings of Vroon (1970). The significant main effect of DUR ($p < .001$) suggests that as the duration of the task increased, so did the subjective duration, as indicated by increases in the mean ratios ($\bar{X}_{30\ sec} = 1.04$; $\bar{X}_{60\ sec} = 1.38$; $\bar{X}_{90\ sec} = 1.66$). This finding conforms with general expectations, although doubling and tripling the task duration with respect to the duration of the standard tone series did not result in doubling or tripling the mean response ratios.

Although both of the above main effects were significant, they must be interpreted in terms of the higher-order interactions. However, in the absence of any other information about a task, the above findings can be considered as valid.

Females Only - Ratio 2

Ratio 2, the second dependent measure, was formed by dividing the apparent duration of the color sequence stated in real-time units by the apparent duration of the tone interval. In this way, Ratio 2 made direct reference to real-time units.

A three-way fixed effects analysis of variance was used to examine the effects of the type of response (RES), stimulus event rate (RAT), and the duration of the task (DUR). The results of the analysis can be seen in Table 11.

As for the Ratio 1 analysis, the main effect of RES ($p < .025$) and DUR ($p < .005$) proved significant. As well, the direction of the effects were the same. That is, as the response complexity increased the subjective duration decreased ($\bar{X}_{0-R} = 1.44$; $\bar{X}_{1-R} = 1.38$; $\bar{X}_{2-R} = 1.22$), and as the task duration increased, so did the subjective duration ($\bar{X}_{30\ sec} = 1.01$; $\bar{X}_{60\ sec} = 1.38$; $\bar{X}_{90\ sec} = 1.65$).

Unlike the analysis of Ratio 1, the main effect of RAT proved significant ($p < .05$). However, as can be seen in Figure 3, and verified by tests for the presence of linear, quadratic, and cubic trend components (Table 12), increasing event rates did not result in linearly increasing response ratios. More detailed comparisons between Ratios 1 and 2 are considered in the Discussion.

Table 7

Analysis of Variance for Females Only, Ratio 1

Source	df	SS	MS	F
Response type (RES)	2	3.4397	2.7199	11.31
Event rate (RAT)	3	0.0403	0.0134	0.06
RES X RAT	6	0.6146	0.1024	0.43
Task duration (DUR)	2	20.7225	10.3613	43.09
RES X DUR	4	1.7217	0.4304	1.79
RAT X DUR	6	1.3950	0.2325	0.97
RES X RAT X DUR	12	12.2540	1.0212	4.25
Within cells	288	69.2438	0.2404	
Total	323	111.4320		

$.05F(3,\infty) = 2.60$ $.01F(12,\infty) = 2.18$

$.05F(4,\infty) = 2.37$ $.005F(3,\infty) = 4.28$

$.05F(6,\infty) = 2.10$ $.0005F(2,\infty) = 7.60$

$.01F(3,\infty) = 3.78$ $.0005F(12,\infty) = 2.90$

Table 8

Cell Means (and Standard Deviations) for Data from Females Only, Ratio 1

Task Duration		30 Seconds			60 Seconds			90 Seconds		
Response Type		0-R	1-R	2-R	0-R	1-R	2-R	0-R	1-R	2-R
	20	1.57(0.43)	0.64(0.28)	1.06(0.31)	1.62(0.49)	1.48(0.86)	1.10(0.19)	1.59(0.50)	1.91(0.70)	1.43(0.60)
Event	40	1.00(0.33)	1.00(0.15)	1.02(0.36)	1.45(0.56)	1.78(0.50)	0.97(0.26)	2.14(0.66)	1.26(0.33)	1.65(0.40)
Rate	60	1.13(0.33)	0.89(0.21)	0.91(0.14)	1.45(0.67)	1.49(0.41)	1.53(0.63)	1.70(0.69)	2.00(0.60)	1.17(0.36)
	80	1.19(0.53)	1.30(0.53)	0.83(0.19)	1.38(0.44)	1.37(0.61)	0.92(0.20)	1.93(0.71)	1.41(0.58)	1.76(0.62)

Table 9

Analysis of Simple Interaction Effects of RES X RAT

Source	df	SS	MS	F
RES X RAT at DUR_{30}	6	3.6120	0.6020	2.50
RES X RAT at Dur_{60}	6	2.1762	0.3627	1.51
RES X RAT at DUR_{90}	6	6.9530	1.1588	4.82
Within cells	288	69.2438	0.2404	

$.05F(6,\infty)= 2.10$

$.0167F(6,\infty)= 2.63$

$.0005F(6,\infty)= 4.02$

Table 10

Differences in Linear, Quadratic, and Cubic Trends in the RES X RAT Interaction at DUR_{90} for Ratio 1

Source	df	SS	MS	F
Diff. in linear trend	2	0.7735	0.3867	1.61
Diff. in quadratic trend	2	0.5374	0.2687	1.12
Diff. in cubic trend	2	5.9034	2.9517	12.28
Within cells	288	69.2438	0.2404	

$_{.05}F(2,\infty) = 3.00$

$_{.0005}F(2,\infty) = 7.60$

Table 11

Tests for Linear, Quadratic, and Cubic Trend Components Within Response Functions for Ratio 1

Source		df	SS	MS	F
RES_{0-R}	linear trend	1	0.1514	0.1514	0.63
	quadratic trend	1	1.3689	1.3689	5.69
	cubic trend	1	1.2400	1.2400	5.16
RES_{1-R}	linear trend	1	0.2599	0.2599	1.08
	quadratic trend	1	0.0075	0.0075	0.03
	cubic trend	1	3.3290	3.3290	13.85
RES_{2-R}	linear trend	1	1.3657	1.3657	5.68
	quadratic trend	1	0.3080	0.3080	1.28
	cubic trend	1	1.4098	1.4098	5.86
Within cells		288	69.2438	0.2404	

$_{.05}F(1,\infty) = 3.84$

$_{.025}F(1,\infty) = 5.02$

$_{.0005}F(1,\infty) = 12.10$

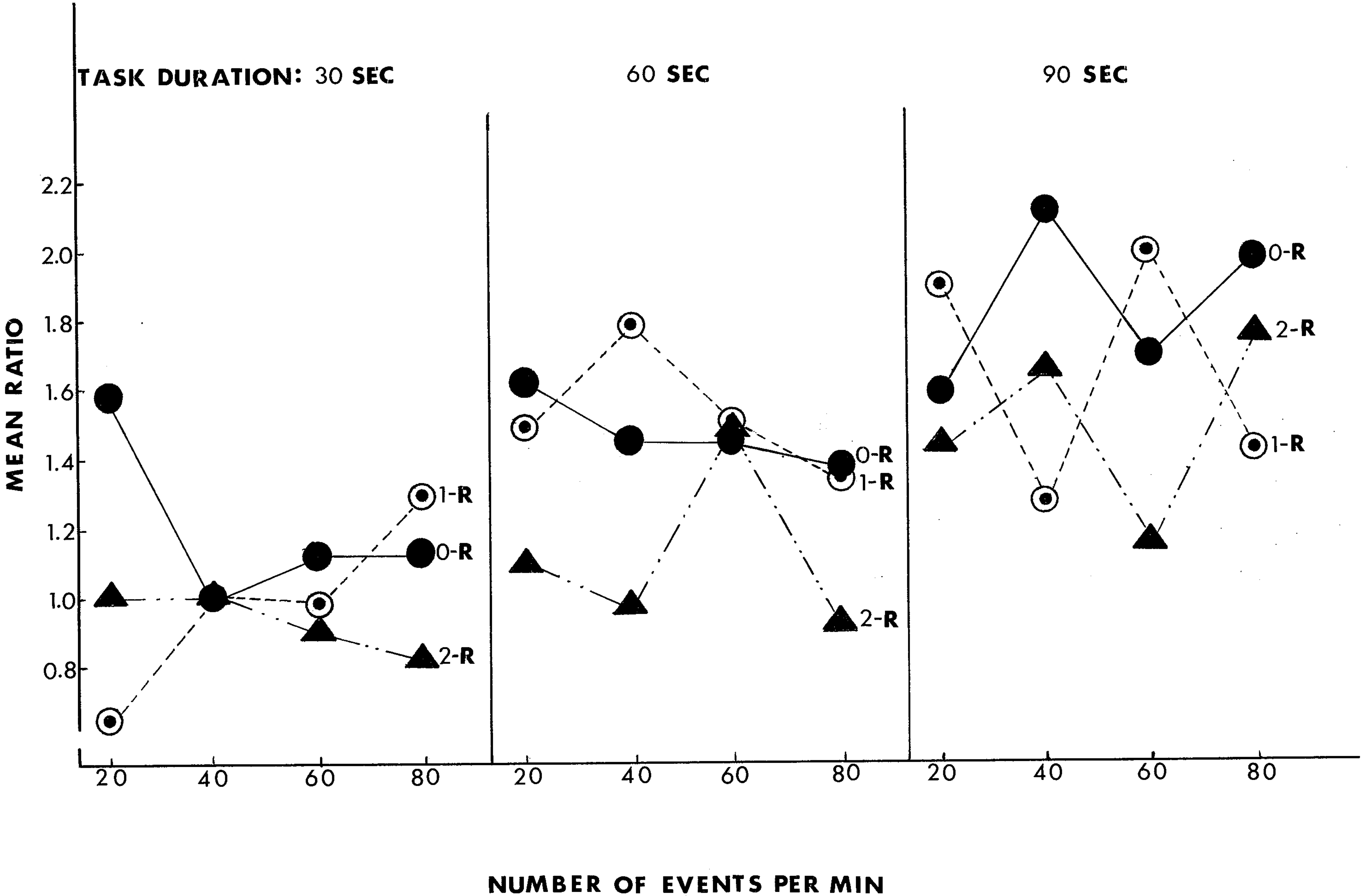
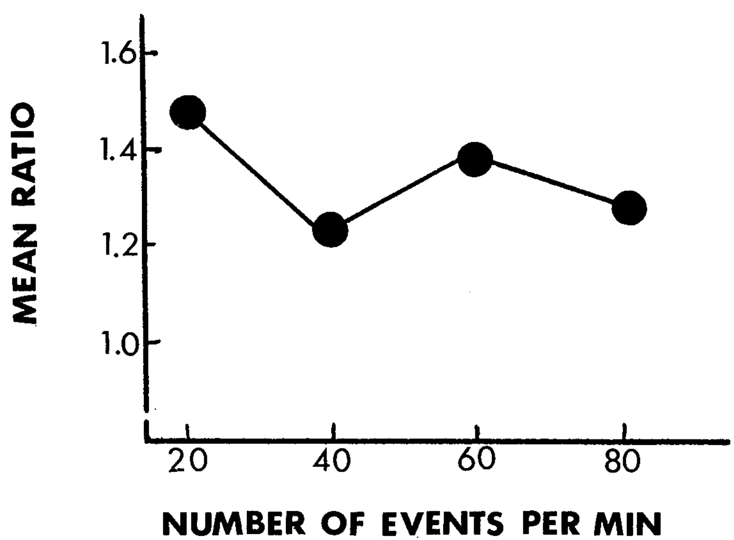


Fig. 2 Response Type by Event Rate Interactions for Ratio 1 in Experiment Two

Fig. 3

Main Effect of Event Rate, Ratio 2



Discussion

The present experiment was designed to examine the effects of response complexity (RES), event rate (RAT), and task duration (DUR) on the subjective duration of a task in the past, that is, one in which it was not known that the duration of the task was important while it was being performed. The analysis of the data showed that the perception of the apparent duration of such intervals should not be considered as a simple process.

The overall difference in the analyses of Ratios 1 and 2 suggests first of all that consideration must be given to the method in which subjective duration is reported -- whether without reference to real-time units (Ratio 1) or with reference to real-time units (Ratio 2). As for the use of Ratio 1 or Ratio 2 in the present type of research, it would seem to be a matter of preference of the investigator. However, Ratio 1 might be a more sensitive measure than Ratio 2. Although non-linear trends across increasing event rates were detected in both analyses, the differences in the direction of variation were present in the analysis of Ratio 1, but not in the analysis of Ratio 2. Furthermore, Ratio 2 may be subject to variables which do not affect Ratio 1. A likely variable would be Ss' preconceptions about the relation between real-time units and their own perceptions of time. Such anchoring effects are always present in absolute judgement methods (Torgerson, 1958, p. 80). For the above reasons, further discussion will center on the results of the analysis of Ratio 1.

One of the two main hypotheses investigated in the present study was that increases in the complexity of the number of events in an interval in the past are reflected by increases in the subjective duration of the intervals (Ornstein, 1969). The hypothesis was neither supported nor rejected by the analysis of the data. In the no-overt response condition (0-R) for a task duration of 90 seconds, which was similar to the no-overt response condition used by Ornstein, increases in the number of events (by increasing the event rate) did not results in a systematic increase in subjective duration. However, is did not result in a systematic decrease either. The presence of cubic and quadratic trend components tends to suggest that simply the number or rate of events in a 90 second interval is not the only factor operating.

This also holds for the most complex response (2-R) and the simple response (1-R), both of which were designed to test the other main hypothesis. The second hypothesis suggests that when Ss overtly respond to stimuli, increases in complexity are reflected by decreases in subjective duration (Vroon, 1970). Although this was found to hold for the main effect of response type, the significant simple interaction effect doeas not strengthen this conclusion. That is, the presence of non-linear trend components in the response functions suggests the presence of unaccounted factors. Just what these factors might be is presently unknown. However, these findings are not unique. Jones and Maclean (1966) and Pachtman (1972) found quadratic and cubic trends across increasing event rates. (Jones and Maclean (1966) made the tenuous suggestion that the non-linear trends may be the result of interactions between stimulus event rates and physiological rhythms).

It is possible that the similarity in the profiles of the 0-R and the 2-R conditions might be attributable to the underlysing similarity of the tasks in both conditions. Although Ss in the 0-R condition were instructed not to make overt responses to each stimulus event, they were instructed to try to detect the presence of a non-existant orange color. Thus, each stimulus event initiated a decision process, as was the case for Ss in the 2-R condition, who had to respond overtly and differentially to red and green events. Subjects in the 1-R condition simply had to respond to the presence of an event, without regard for its color. One of the unknown factors, then, might be the complexity of the task, with little regard for overt responding.

Another important consideration may be that the task had to be recalled when its duration was being assessed. It could be that an additional unknown factor is related either to the storage or to the retrieval of the task, or perhaps to the metering or "timing" of the recalled event. For example, one set of chunking procedures might be operative for complex responses, and another set for simple responses. Effects associated with storage processes could be investigated by examining changes in the shapes of the response functions as the delay between the experimental task and the questionnaire is increased. It should be added that in the present study, the delay was about 20 seconds, which was similar to the delay used by Ornstein (1969). Perhaps one reason why predominantly linear effects were not obtained in the present study is that for the tasks involved a delay of 20 seconds might not have been sufficient to complete the "idle-active" transformation (Cohen, 1967). However, the nature of the transformation is not unkown, nor is the required delay known.

As in Experiment 1, the 2-R X 80 per minute event rate treatment combination seemed to have resulted in an exces of channel capacity. Confining consideration to the 90 second task duration condition, it can be seen (Fig. 3) that this treatment combination did not result in an inordinate estimate of the task duration. It can be concluded then, that the effect that exceeding channel capacity had on the estimation of current intervals did not occur in the process of estimating the relative subjective durations of intervals in the past.

Further research would likely involve durations of 90 seconds or longer, since the response functions in the present study did not stabilize at the 30 or 60 second suration conditions. As well, retention intervals between the task and the questionnaire would be manipulated.

Supplementary Data

Males Only - Results and Discussion

Ratios were formed for the data from the males in the same manner as for the females. Two three-way unweighted means analyses of variance were performed on the data. The independent variables were the same as in the females only analyses. The number of Ss per cell ranged from 5 to 2. The results of the analyses, shown in Table 12 for Ratio 1 and Table 13 for Ratio 2, must be considered very cautiously. Since an unweighted means analysis weights each cell mean equally, even if there are more Ss in some cells than in others, there is a loss in precision in defining sources of variation. This loss is reflected in the "Error due to approximation" in Tables 12 and 13.

The analysis of Ratio 1 shows that the main effects of RES ($p < .05$) and DUR ($p < .001$) and the RES X DUR interaction ($p < .01$) were significant. As for the females, the mean ratios decreased for increasing response complexity, and increased for increasing task duration. Unlike the similar analysis of the data from females (see Table 7), the effect of the RES X RAT X DUR interaction was not significant. This might suggest that for males, stimulus event rate may not be a salient attribute with respect to subjective duration.

The analysis of the Ratio 2 data (Table 13) shows that only the main effect of DUR ($p < .001$) and the RES X DUR interaction ($p < .01$) were significant. Thus, the results of the analysis bear little similarity to the results of the analysis of Ratio 2 for the females.

The supplementary nature of these results must be emphasized. The small cell n in many cells, as well as the unequal distribution of Ss, greatly limits the extensibility of these findings.

Table 12

Analysis of Variance for Males Only, Ratio 1

Source	df	SS	MS	F
Response type (RES)	2	3.2283	1.6141	4.93
Event rate (RAT)	3	0.6058	0.2019	0.62
RES X RAT	6	4.0433	0.6739	2.06
Task Duration (DUR)	2	14.4165	7.2083	22.03
RES X DUR	4	6.4275	1.6069	4.91
RAT X DUR	6	1.8407	0.3068	0.94
RES X RAT X DUR	12	3.0779	0.2565	0.78
Within cells	74	24.2177	0.3273	
Error due to approximation*		-3.4651		
Total	109	54.3927		

*see discussion of supplementary data

$.05F(2,74) = 3.12$

$.05F(6.74) = 2.22$

$.01F(4,74) = 3.58$

$.001F(2,74) = 7.59$

Table 13

Analysis of Variance for Males Only, Ratio 2

Source	df	SS	MS	F
Response type (RES)	2	0.8254	0.4127	0.17
Event rate (RAT)	3	0.7113	0.2371	0.10
RES X RAT	6	22.8305	3.8051	1.59
Task duration (DUR)	2	40.7549	20.3774	8.50
RES X DUR	4	46.2045	11.5511	4.82
RAT X DUR	6	17.3739	2.8957	1.21
RES X RAT X DUR	12	32.4572	2.7048	1.13
Within cells	74	177.3381	2.3965	
Error due to approximation*		-1.0497		
Total	109	337.4460		

*see discussion of supplementary data

$.05F(6,74) = 2.22$

$.05F(12,74) = 1.89$

$.01F(4,74) = 3.58$

$.0001F(2,74) = 7.59$

General Discussion and Conclusions

The purpose of the present investigations was to test two theories of Man's perception of the duration of the intervals in the present, as they are being experienced, and in the past, when the duration of the interval was not of interest. The biological clock hypothesis was discussed first in terms of attempts to define or locate the rhythmical organismic process which may be the basis of the internal clock. In general, these attempts have failed. However, indirect evidence for an internal clock could be obtained by placing Ss in particular experimental situations, as in Experiment 1. Experiment 1 was also a test of the cognitive clock hypothesis which explains Man's perception of time as being directly related to the succession of events. The results of Experiment 1 were not conclusive. Although it was found in one condition that increasing complexity resulted in increasing reproduction intervals, thereby giving some support to the biological clock hypothesis, the lack of this finding in other conditions weakens this support. The presence of non-linear trends across linear increases in event rates for the most complex response type suggests that unaccounted factors are involved in the assessment of the subjective duration of intervals in the present.

Experiment 2 was not a direct test of the biological versus the cognitive clock theory, but was designed to examine the roles of response complexity (in particular overt versus covert responding), stimulus event rate, and task duration in the process of assessing the subjective duration of intervals in the past. Since the interval of interest was in the past, it would be reasonable to expect that "cognitive" processes were operative in the estimation of the interval's duration. However, just what the cognitive process might be is not known. In general, Ornstein's (1969) storage size hypothesis in which subjective duration is directly related to the "size" of the remembered event was not supported.

Finally, the complexities of the results of the present studies emphasize the necessity for multi-factor designs to investigate subjective duration. Only such experiments can begin to approximate the intracacies of subjective duration.

References

Adam, N. Mechanisms of time perception. Journal of Life Sciences, 1971, 1, 41-52.

Adam, N., Rosner, B. S., Hosick, E. C., & Clark, L. Effect of anesthetic drugs on time perception and alpha rhythm. Perception and Psychophysics, 1971, 10, 133-136.

Bindra, D. & Waksberg, H. Methods and terminology in studies of time estimation. Psychological Bulletin, 1956, 53, 155-159.

Boring, E. G. Sensation and perception in the history of experimental psychology. New York: Appleton-Century-Crofts, Inc., 1942.

Burnside, W. Judgement of short time intervals while performing mathematical tasks. Perception and Psychophysics, 1971, 9, 404-406.

Cahoon, R. L. Physiological arousal and time estimation. Perceptual and Motor Skills, 1969, 28, 259-268.

Carlson, V. R. & Feinberg, I. Time judgement as a function of method of practice and sex. Journal of Experimental Psychology, 1970, 85, 171-180.

Carlson, V.R., Goodenough, D. R., & Feinberg, I. Time perception and sleep. Psychophysiology, 1968, 5, 242.

Clausen, J. An evaluation of experimental method and time judgement. Journal of Experimental Psychology, 1950, 40, 756-761.

Cloudsley-Thompson, J. L. Time sense in animals. In J.T. Fraser (Ed.), The voices of time. New York: George Braziller, 1966.

Cohen, J. Psychological time in health and disease. Springfield, Ill.: Charles C. Thomas, 1967.

Denis, M. L'éstimation de la duree cinematographique en fonction de la structure du message. Annèe Psychologique, 1971, 71, 139-151.

Deutsch, J. A. & Deutsch, D. Physiological Psychology, Homewood, Ill.: The Dorsey Press, 1966.

Dobson, W. R. An investigation of the various factors of time perception as manifested by various nosological groups. Journal of General Psychology, 1954, 50, 277-298.

Emley, S. S., Shuster, C. R., & Lucchesi, B. Trends observed in the time estimation of three stimulus intervals within and across sessions. Perceptual and Motor Skills, 1968, 26, 391-398.

Falk, J. L. & Bindra, D. Judgement of time as a function of serial position and stress. Journal of Experimental Psychology, 1954, 47, 279-282.

Fraisse, P. The psychology of time. New York: Harper and Row, 1963.

Friel, C. M. & Lhamon, W. T. Gestalt study of time estimation. Perceptual and Motor Skills, 1965, 21, 603-606.

Gaeschk, J. K., Kintz, B. L., & Thompson, R. W. Stimulus complexity, free looking time, and inspective exploration. Perception and Psychophysics, 1968, 4, 319-320.

Goldstone, S., Boardman, W. K., & Lhamon, W. T. Effects of quinalbarbitone, dextro-amphetamine and placebo on apparent time. British Journal of Psychology, 1958, 49, 324-328.

Gulliksen, H. The influence of occupation upon the perception of time. Journal of Experimental Psychology, 1927, 10, 52-59.

Harter, M. R. Excitability cycles and cortical scanning: Areview of two hypotheses of central intermittency. Psychological Bulletin, 1967, 68, 47-58.

Hawkins, N. E. & Myers, M. E. Time perception of short intervals during finished, unfinished and empty task situations. Psychonomic Science, 1965, 3, 473.

Hoagland, H. The physiological control of judgements of duration: Evidence for a chemical clock. Journal of General Psychology, 1933, 9, 267-287.

Holubar, J. The sense of time. Cambridge, Mass.:The M.I.T. Press, 1969.

Hoyer, W. J. & Jones, E. C. Effects of knowledge of the ITI on time estimates: Method of production. Perceptual and Motor Skills, 1970, 31, 709-710.

Hoyer, W. J., Jones, E. C., White, R. S., & Maconacky, W. V. Effects of knowledge of the ITI on time estimates. Perceptual and Motor Skills, 1970, 31, 392-394.

James, W. Principles of psychology. New York: Holt, Rinehart, and Winston, 1890, (2 vols.).

Jones, A. & Maclean, M. Perceived duration as a function of auditory stimulus frequency. Journal of Experimental Psychology, 1966, 358-364.

Kirk, R. E. Experimental design: Procedures for the behavioral sciences. Belmont, Cal.: Brooks/Cole, 1968.

Legg, C. F. Alpha rhythm and time judgements. Journal of Experimental Psychology, 1968, 78, 46-49.

Lockhart, J. M. Ambient temperature and time estimation. Journal of Experimental Psychology, 1967, 73, 286-295.

Loehlin, J. C. The influence of different activities on the apparent length of time. Psychological Monographs, 1959, 73 (Whole #474).

Maloney, T. & Callaway, E. The effect of repeated presentation of a standard interval on the reproduction of the standard. Perception and Psychophysics, 1971, 10, 356-357.

McConchie, R. D. The influence of knowledge of results and method of estimation of short temporal intervals. Dissertation Abstracts International, 1970, 30(10-B), 4817-4818.

McConchie, R. D. & Rutschmann, J. Human time estimation: On differences between methods. Perceptual and Motor Skills, 1971, 32, 319-336.

Ochberg, F. M. & Triester, B. Effect of pulse on time estimation using subjects with fixed cardiac pacemakers. Perceptual and Motor Skills, 1970, 30, 907-915.

Ornstein, R. E. On the experience of time. Baltimore: Penguine Books, 1969.

Pachtman, E. Relationship between memory and estimates of short duration as a function of auditory stimulus frequency.(Doctoral dissertation, Arizona State University). Ann Arbor, Mich.:1972, No. 72-1594.

Pfaff, D. Effects of temperature and time of day on time judgements. Journal of Experimental Psychology, 1968, 76, 419-422.

Pieron, H. Les problemes psychophysiologiques de la perception du temps. Annèe Psychologique, 1923, 24, 1-25.

Ross, D. A. Time estimation and brain rhythms. Dissertation Abstracts, 1968, 29(5-B), 1964.

Schaeffer, V. G. & Gilliland, A. R. The relation of time estimation to certain physiological changes. Journal of Experimental Psychology, 1938, 23, 545-552.

Shectman, F. A. Time estimation sequence effects and filling activities. Perceptual and Motor Skills, 1970, 30, 23-26.

Smith, N. C. The effect on time estimation of increasing complexity of a cognitive task. Journal of General Psychology, 1969, 81, 231-235.

Stott, L. H. Time order errors in the discrimination of short tonal durations. Journal of Experimental Psychology, 1935, 18, 741-766.

Swift, E. J. & McGeoch, J. R. An experimental study of the perception of filled and empty time. Journal of Experimental Psychology, 1925, 8, 240-249.

Torgerson, W. S. Theory and methods of Scaling. New York: John Wiley & Sons, Inc., 1958.

Vroon, P. A. Effects of presented and processed information on duration experience. Acta Psychologica, 1970, 34, 115-121.

Warm, J. & McCray, R. E. Influence of word frequency and length on the apparent duration of tachistoscopic presentations. Journal of Experiemmental Psychology, 1969, 79, 56-58.

Watts, A. Psychedelics and religious experience. In B. Aatonson and H. Osmond (Eds.), Psychedelics: The uses and implications of hallucinogenic drugs. New York: Doubleday and Co., Inc., 1970.

Woodrow, H. The effects of practice upon time order errors in the comparison of temporal intervals. Psychological Review, 1935, 42, 127-252.

Woodwarth, R. S. & Schlosberg, H. Experimental psychology. New York: Holt, 1954.

Zelkind, I. & Bachuber, M. Geometric correlates of temporal durations: Signs of the times. Perceptual and Motor Skills, 1970, 31, 971-974.

Zung, W. W. & Wilson, W. P. Time estimation during sleep. Biological Psychiatry, 1971, 3, 159-164.

Appendix A

Data from Experiment One: Reproduction Intervals (in Seconds) as a Function of Type of Response (0-R, 1-R, and 2-R) and Event Rate (20, 40, 60, and 80 per Min)

Response Type		Event Rate 20	40	60	80
	0-R	90.20	50.94	13.95	19.20
		67.73	15.54	72.95	16.40
		46.11	41.02	85.59	44.12
		49.35	12.88	19.96	23.02
		45.85	33.21	21.64	55.49
		93.60	17.34	68.22	24.45
		28.29	32.55	31.00	21.21
		43.70	20.02	24.70	21.12
		57.52	20.15	32.74	60.71
	1-R	64.81	25.72	64.05	30.87
		101.98	29.89	66.03	33.20
		80.20	43.86	52.72	104.81
		81.12	89.10	20.36	22.65
		33.80	45.76	37.38	25.92
		31.44	75.59	32.24	17.41
		60.49	47.91	19.72	73.81
		51.72	41.96	109.45	106.83
		20.11	32.42	59.36	54.46
	2-R	19.15	29.07	26.78	108.44
		54.43	36.31	50.06	79.23
		17.00	36.41	51.98	131.05
		30.74	20.42	49.49	35.91
		57.42	38.05	16.64	16.40
		75.90	78.14	19.95	97.11
		86.82	54.78	15.49	77.87
		43.12	78.00	39.11	35.13
		22.66	53.06	14.68	82.22

Appendix B

Data from Experiment Two: Subjects' Response Ratios as a Function of

Response Type, Event Rate, and Task Duration

(Cell identification: response type/event rate/task duration/sex)

0-R/20/30/F	Ratio 1:	1.00	1.00	1.40	1.52	1.58	1.90	1.40	2.20	2.08
	Ratio 2:	1.00	1.00	1.33	1.67	2.00	2.00	1.50	2.00	1.25
0-R/20/30/M	Ratio 1:	1.00	1.16	1.78	2.00					
	Ratio 2:	1.00	1.33	0.80	2.00					
0-R/20/60/F	Ratio 1:	1.60	1.00	1.84	1.72	2.32	1.02	1.22	2.28	1.62
	Ratio 2:	2.00	1.00	2.00	2.40	2.00	1.00	1.08	3.00	1.50
0-R/20/60/M	Ratio 1:	1.44	2.14	1.00						
	Ratio 2:	0.80	2.00	1.00						
0-R/20/90/F	Ratio 1:	1.10	1.00	0.84	1.70	1.54	1.80	2.06	2.12	2.16
	Ratio 2:	1.30	0.83	0.83	2.00	2.50	3.00	2.00	2.00	3.00
0-R/20/90/M	Ratio 1:	3.20	1.36	3.48						
	Ratio 2:	2.00	1.33	4.00						
0-R/40/30/F	Ratio 1:	0.70	1.20	1.70	0.88	1.02	0.50	1.00	0.94	1.02
	Ratio 2:	0.50	1.50	2.00	1.50	1.00	1.50	1.00	1.00	1.00
0-R/40/30/M	Ratio 1:	1.00	1.02	1.28	1.00					
	Ratio 2:	1.00	1.23	1.00	1.00					
0-R/40/60/F	Ratio 1:	1.00	1.38	1.14	1.16	1.00	2.26	2.54	1.38	1.18
	Ratio 2:	1.00	1.33	1.50	1.17	1.00	2.00	3.00	1.50	1.50
0-R/40/60/M	Ratio 1:	1.02	1.54	2.52	0.76					
	Ratio 2:	1.00	1.75	3.00	0.67					
0-R/40/90/F	Ratio 1:	2.16	2.44	3.50	2.18	1.84	2.14	1.06	2.30	1.66
	Ratio 2:	0.50	1.03	2.00	2.00	1.44	2.00	3.00	1.00	1.50
0-R/40/90/M	Ratio 1:	2.70	2.54							
	Ratio 2:	2.50	2.40							
0-R/60/30/F	Ratio 1:	1.60	1.02	1.50	1.90	1.00	0.54	1.02	1.28	1.32
	Ratio 2:	1.40	1.00	1.33	0.75	1.00	0.67	1.00	0.67	1.33
0-R/60/30/M	Ratio 1:	1.96	0.88	0.88	2.16					
	Ratio 2:	9.99	0.91	0.83	2.00					
0-R/60/60/F	Ratio 1:	0.76	1.02	1.24	2.56	2.26	1.44	0.76	1.00	2.02
	Ratio 2:	0.75	1.00	2.00	1.50	2.00	1.67	1.00	1.00	2.25
0-R/60/60/M	Ratio 1:	0.84	1.00							
	Ratio 2:	0.75	1.00							
0-R/60/90/F	Ratio 1:	1.70	2.28	1.38	1.16	1.28	3.10	1.02	1.20	2.20
	Ratio 2:	2.00	2.00	1.50	1.33	2.00	2.40	1.00	1.17	2.00
0-R/60/90/M	Ratio 1:	2.04	4.40	3.22						
	Ratio 2:	5.00	9.99	6.00						
0-R/80/30/F	Ratio 1:	0.72	1.00	1.02	1.00	1.20	2.16	1.98	1.00	0.64
	Ratio 2:	0.67	1.00	1.25	1.00	1.00	2.00	1.50	1.00	0.67
0-R/80/30/M	Ratio 1:	0.98	1.30	1.02						
	Ratio 2:	1.00	1.00	1.42						
0-R/80/60/F	Ratio 1:	1.58	1.00	1.56	0.72	1.30	2.24	1.00	1.54	1.50
	Ratio 2:	1.25	1.00	0.67	1.50	1.33	2.00	1.00	1.50	1.20

Appendix B (Cont'd)

0-R/80/60/M Ratio 1: 1.40 1.50 0.90
Ratio 2: 2.00 0.67 0.92
0-R/80/90/F Ratio 1: 1.00 2.32 1.52 0.86 2.04 2.16 2.62 1.84 3.02
Ratio 2: 1.00 1.83 1.47 0.50 2.00 1.00 3.00 1.33 3.00
0-R/80/90/M Ratio 1: 2.06 1.84 2.32
Ratio 2: 2.00 2.00 4.00
1-R/20/30/F Ratio 1: 1.00 0.72 0.72 0.78 0.10 0.40 0.38 0.84 0.78
Ratio 2: 1.00 0.83 0.75 0.75 0.08 0.03 1.50 0.75 0.67
1-R/20/30/M Ratio 1: 1.52 1.86 0.88
Ratio 2: 2.00 0.50 0.80
1-R/20/60/F Ratio 1: 2.50 3.00 0.76 0.46 1.04 1.00 1.88 1.46 1.10
Ratio 2: 2.00 3.00 0.60 0.20 1.00 1.00 2.00 0.67 1.00
1-R/20/60/M Ratio 1: 0.86 1.50 0.86
Ratio 2: 0.80 1.50 8.00
1-R/20/90/F Ratio 1: 3.44 1.18 2.24 1.26 2.34 1.80 1.50 1.88 1.58
Ratio 2: 2.50 1.17 1.22 1.50 2.50 2.25 1.67 3.00 4.00
1-R/20/90/M Ratio 1: 1.12 2.24 1.00 1.18
Ratio 2: 1.56 1.00 1.00 1.20
1-R/40/30/F Ratio 1: 0.76 0.80 1.18 1.00 1.22 1.00 1.00 1.00 1.00
Ratio 2: 0.67 0.67 1.11 1.00 1.50 1.00 1.25 1.00 1.00
1-R/40/30/M Ratio 1: 1.92 0.50 1.14 1.68
Ratio 2: 2.00 0.50 1.00 0.38
1-R/40/60/F Ratio 1: 1.88 2.24 1.54 0.90 1.86 1.34 2.32 2.44 1.54
Ratio 2: 1.33 1.50 2.00 0.88 0.67 1.33 0.50 1.50 1.73
1-R/40/60/M Ratio 1: 1.56 1.04
Ratio 2: 1.20 1.00
1-R/40/90/F Ratio 1: 1.34 1.04 1.46 1.28 1.28 0.94 0.86 1.98 1.12
Ratio 2: 1.33 1.00 1.33 2.50 0.83 1.33 0.90 3.00 1.08
1-R/40/90/M Ratio 1: 1.02 1.54
Ratio 2: 1.00 3.00
1-R/60/30/F Ratio 1: 1.10 1.00 0.88 0.88 1.00 0.74 1.16 0.50 0.72
Ratio 2: 1.25 1.00 0.83 0.67 1.00 0.83 1.50 0.50 0.80
1-R/60/30/M Ratio 1: 0.92 0.92 1.36
Ratio 2: 1.12 0.83 1.50
1-R/60/60/F Ratio 1: 1.42 1.40 1.00 1.40 2.32 1.74 1.32 1.00 1.80
Ratio 2: 1.33 4.50 1.00 2.00 2.00 2.00 1.67 0.63 1.67
1-R/60/60/M Ratio 1: 1.00 1.28 3.00 1.56
Ratio 2: 1.00 3.00 4.00 1.50
1-R/60/90/F Ratio 1: 1.49 1.82 1.74 2.50 2.82 2.18 2.38 0.82 2.26
Ratio 2: 1.25 2.25 1.75 2.11 2.00 2.00 1.60 0.50 2.50
1-R/60/90/M Ratio 1: 3.18 1.76 1.68
Ratio 2: 3.00 2.00 0.43
1-R/80/30/F Ratio 1: 1.76 2.08 0.82 1.44 0.90 1.04 0.76 2.00 0.92
Ratio 2: 0.67 2.00 0.80 1.20 0.80 1.00 0.76 2.00 0.80
1-R/80/30/M Ratio 1: 1.02 0.22
Ratio 2: 1.00 0.30
1-R/80/60/F Ratio 1: 0.56 1.76 0.94 1.02 1.02 1.52 2.20 2.32 1.00
Ratio 2: 0.50 1.50 0.83 3.00 1.00 1.50 2.00 173 1.00
1-R/80/60/M Ratio 1: 0.98 1.30 1.02
Ratio 2: 1.00 2.00 9.99
1-R/80/90/F Ratio 1: 1.00 1.00 2.46 1.08 1.82 1.00 2.16 1.00 1.20
Ratio 2: 1.00 1.00 2.00 1.18 1.50 1.00 3.00 1.00 1.50
1-R/80/90/M Ratio 1: 0.88 1.96 0.67
Ratio 2: 0.95 2.67 0.67

Appendix B (Cont'd)

2-R/20/30/F	Ratio 1:	1.44	0.98	0.78	0.82	0.84	1.00	1.72	1.00	1.00
	Ratio 2:	1.33	1.20	0.83	0.67	0.67	1.00	1.50	1.00	1.00
2-R/20/30/M	Ratio 1:	1.00	1.52	1.00	0.92					
	Ratio 2:	1.00	1.00	1.50	0.80					
2-R/20/60/F	Ratio 1:	0.96	1.00	1.00	1.00	1.00	1.00	1.40	1.44	1.08
	Ratio 2:	0.83	2.00	1.00	1.50	1.25	1.00	1.50	1.50	1.16
2-R/20/60/M	Ratio 1:	1.82	1.94							
	Ratio 2:	3.00	2.46							
2-R/20/90/F	Ratio 1:	1.80	2.44	0.82	1.02	2.20	1.20	0186	1.02	1.50
	Ratio 2:	2.00	2.50	0.80	3.00	2.33	1.00	0.67	1.00	1.50
2-R/20/90/M	Ratio 1:	1.74	1.00	1.32	1.84	1.58				
	Ratio 2:	1.50	1.00	1.23	4.00	1.67				
2-R/40/30/F	Ratio 1:	0.88	0.72	1.02	1.76	0.74	1.44	0.64	1.00	1.00
	Ratio 2:	0.67	0.50	1.00	1.44	0.67	2.00	0.38	1.00	1.00
2-R/40/30/M	Ratio 1:	1.90	1.02							
	Ratio 2:	1.67	1.00							
2-R/40/60/F	Ratio 1:	1.00	1.00	0.68	0.70	1.00	1.02	1.00	1.56	0.76
	Ratio 2:	1.00	1.00	0.60	0.75	0.50	1.00	1.00	1.80	0.50
2-R/40/60/M	Ratio 1:	1.14	1.82	2.10						
	Ratio 2:	1.33	8.75	2.00						
2-R/40/90/F	Ratio 1:	1.02	1.82	2.26	1.34	1.50	1.34	1.96	2.04	1.56
	Ratio 2:	1.00	1.50	1.50	2.00	2.00	1.00	2.25	2.00	1.50
2-R/40/90/M	Ratio 1:	1.90	1.12							
	Ratio 2:	3.60	1.38							
2-R/60/30/F	Ratio 1:	0.98	1.00	0.72	0.90	0.86	1.00	1.04	0.66	1.02
	Ratio 2:	1.00	1.30	0.88	0.89	0.90	1.00	1.00	0.33	1.00
2-R/60/30/M	Ratio 1:	0.64	0.40							
	Ratio 2:	o.60	0.75							
2-R/60/60/F	Ratio 1:	1.00	2.26	1.60	1.24	2.06	1.00	2.62	1.00	1.00
	Ratio 2:	1.00	2.00	2.00	1.17	2.00	1.00	2.00	1.00	1.00
2-R/60/60/M	Ratio 1:	0.72	1.58	1.64						
	Ratio 2:	0.83	3.00	1.50						
2-R/60/90/F	Ratio 1:	1.10	1.00	1.46	0.78	1.02	0.58	1.50	1.44	1.64
	Ratio 2:	1.50	1.00	1.50	0.75	1.00	0.50	2.67	2.00	1.67
2-R/60/90/M	Ratio 1:	2.12	1.00	1.34	1.84					
	Ratio 2:	2.00	1.00	1.50	1.50					
2-R/80/30/F	Ratio 1:	1.02	0.80	0.68	1.00	1.00	0.50	1.00	0.88	0.62
	Ratio 2:	1.00	0.83	0.50	1.00	1.00	0.16	1.00	0.83	0.67
2-R/80/30/M	Ratio 1:	1.62	0.80	0.86	1.00					
	Ratio 2:	1.50	0.80	0.86	1.00					
2-R/80/60/F	Ratio 1:	1.02	1.20	0.82	1.02	0.72	1.02	1.02	0.90	0.56
	Ratio 2:	1.00	1.50	0.83	1.00	0.75	1.00	1.00	0.67	2.00
2-R/80/60/M	Ratio 1:	1.24	2.42	1.58						
	Ratio 2:	1.33	4.50	1.33						
2-R/80/90/F	Ratio 1:	1.56	1.30	1.00	2.64	2.70	1.34	1.32	2.16	1.86
	Ratio 2:	1.00	1.33	1.50	1.33	2.25	1.25	1.50	2.00	2.00
2-R/80/90/M	Ratio 1:	2.64	1.86							
	Ratio 2:	2.25	2.00							