THE REPETITION EFFECT IN SHORT TERM MOTOR MEMORY RETRIEVAL

by

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ABSTRACT

The main purpose of this study was to investigate a theory of information storage and retrieval of a simple motor task as an explanation of the repetition effect (RE) in a 2-choice reaction time task. Subsidiary problems involved 1) examining the effect of inter-trial interval (ITI) on RE, 2) examining the effect of probability (P) of occurrence of an S-R pair on the RE and, 3) examining the interacting effects of ITI and P on the RE.

The experimental task was a 2-choice reaction time (RT) task where the subject had to respond as quickly as possible by depressing a response key following the onset of a stimulus light. Two types of tasks were used: 1) self-paced, in which the ITI was approximately 380 msec. and, 2) discrete, in which the ITI was approximately 1600 msec. Each subject was tested in both tasks and on all three probability conditions (P = .33, .50, .67).

Sixteen students and staff of the University of British Columbia served as subjects.

The results, which were somewhat tenuous due to equipment malfunctions, indicated that there was no RE in either the discrete or serial CRT task. This suggested that there were no differences in the subjects response strategies in either the discrete or serial task. The model of motor memory retrieval was not supported by this investigation.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

In order to understand the process of learning and performing motor skills it is necessary to understand the process by which skills are stored and retrieved from memory. Most researchers in the field agree that memory storage is divided into at least two areas: a short term or primary memory (PM) storage area of limited capacity but high accessibility, and a long term or secondary memory (SM) store of unlimited capacity but less accessibility (Shiffrin and Atkinson, 1969). Others propose a third area of storage, that of an immediate memory or selective attention (SA) store (Falmagne, 1965; Norman, 1969; Schutz, 1972). SA, which is thought to have a capacity of only one program usually contains the program for the response having the highest subjective probability of occurrence.

Reaction time experiments afford an opportunity for establishing an exact quantitative theory, and for this reason have been utilized by many researchers as a measure of search, retrieval, and recognition time in PM and SM (e.g. Keele, 1969). Schutz (1972, 59) suggests that:

When a response is called for by presentation of a certain stimulus, the following progression of events takes place:
1. the stimulus is perceived
2. the stimulus is categorized as being one of a number of possible stimuli.
3. the name (or number, or code) of the required response to the perceived stimulus is determined.
4. the response program (RP) is searched for, found, and discharged from a memory storage area to the motor effector system.
5. the neural pathways carry out the instructions released by RP and elicit the required response.

Stage 4 can be further broken down into the search and retrieval time for each memory store. It is assumed that when a stimulus is presented, the template corresponding to the stimulus can be in a SA state, or in a PM state, or in a SM state, these states being mutually exclusive (Falmagne and Theois, 1968). Then once the stimulus is perceived and categorized, and the name of the required response code determined, the response program (RP) is searched for, first in SA, which takes time t_1, if not found there PM is searched, which takes time t_2, then if not found in PM, SM is searched, taking time t_3. Thus is should take a shorter time to search and retrieve a RP if it is in SA. The problem to which this study is directed then is to determine if the above can account for a specific set of experimental results established in CRT studies, namely, those to do with the repetition effect, ITI, and probability.

Sequential effects have been found in serial reaction time experiments such that, under some conditions, response to a signal which is the same as the preceding signal are faster than if it is different (e.g. Bertelson, 1961; Hale, 1969). Bertelson termed this the 'repetition effect'. Under other conditions the opposite has been found, the response to a signal which is different from the preceding signal being faster than if it is the same (e.g. Williams, 1966). Generally, the repetition effect takes place at inter-trial intervals (ITI) of less then 1 sec., while a negative repetition effect, or alternation effect takes place at ITIs of over 1 sec. (Kirby, 1972). If the subject has time to prepare himself for the more probable stimulus by placing the appropriate RP in SA, this would explain the alternation effect in a discrete 2-choice reaction time task. That is, due to what is termed the 'gamblers fallacy' people tend to think an alternation is a more probable event than a repetition in an equal probability situation (Jarvick, 1951). On the other hand, at extremely short ITIs, the subject has no time to prepare for the next stimulus, and the previous engram might still be in SA, thus mediating the repetition effect.

Response probability also affects CRT, as shown by the general agreement that the higher the response probability, the faster the reaction time (Bertelson, 1965; Kornblum, 1967; Moss et al., 1967). This effect appears to be confounded with the repetition effect, as the more probable the stimulus, the more frequent repeated S-R pairs occur. The above explanation of memory search and retrieval could also account for the effects of probability on CRT. That is, in the discrete task, the subject prepares for the more probable stimulus by placing the appropriate RP in SA. However, using the same argument as above, probability should have no bearing on RT in the serial self-paced task, as the subject has no time to prepare.

Statement of the Problem

The purpose of this study is to investigate the theory of information storage and retrieval of a simple motor task, as proposed by Schutz (1972), as an explanation of the repetition effect in a 2-choice reaction time task.

Subproblems

The subproblems are:

1. To determine the effect of inter-trial interval on the repetition effect.

2. To determine the effect of probability of occurrence of an S-R pair on the repetition effect.

3. To determine the interacting effects of inter-trial interval and probability of occurrence on the repetition effect.

Hypotheses

The Hypotheses are:

1. In the serial self-paced task there is a repetition effect (which asymptotes after one repetition), while in the discrete task there is a negative repetition effect (which does not asymptote at one repetition).

This is based on a review of the literature, where some researchers reported a repetition effect, and others a negative repetition effect, the main procedural difference being in length of ITI. The model of memory retrieval suggests this hypothesis since in the serial task, the previous engram is still thought to be in selective attention, while in the discrete task the subject places the alternate stimulus in SA a good part of the time, and even more so after a repetition of the previous stimulus.

2. The probability of occurrence has no effect in the serial self-paced task.

Since the previous engram is still in immediate memory, search and retrieval time and hence response latency is at a minimum.

3. The low probability, in the discrete case, results in the longest RL, while the high probability results in the shortest RL.

This is hypothesized since the subject in the high probability case prepares for the more probable stimulus, placing the appropriate RP in SA.

Definitions of Terms[1]

The following definitions reflect the common usage of the key words used in the literature on memory.

Memory The registration, conscious or unconscious, cortical or subcortical, of past experiences whether these experiences be thoughts, motor acts, sound, smells, verbalizations, etc.

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[1] The following definitions are as defined by Schutz (1972).

Selective attention (SA) A limited capacity memory store capable of containing only one engram at a time. Decay occurs very rapidly in the absence of reinforcement.

Primary memory storage area (PM) A memory store for items recently perceived. It has a limited capacity as to the number of items it can contain and a limited time period of retention of these items. Primary memory is analogous to "short-term memory (STM)", and "immediate memory (IM)".

Secondary memory storage area (SM) A memory store containing items which have been perceived and reinforced and then absent from consciousness for a period of time. This storage system has an unlimited capacity as to the number of items it can contain. Secondary memory is analogous to "long-term memory (LTM)".

Memory trace An item stored in SA, PM or SM, in some sort of visual, neural, or chemical code. It is synonomous to the term "engram", or "template".

Reaction time (RT) The time elapsing from the presentation of a stimulus to the initiation of the associated response. If more than one response is possible, and a decision has to be made as to which response to make, then the elapsed time is called "choice reaction time (CRT)". The term "response latency" is synonomous with reaction time.

Stimulus probability The probability that a specific stimulus will be presented on a particular trial of a CRT task.

Inter-trial interval (ITI) The time elapsing between the last response and the next presentation of the stimulus.

Delimitations

1. The study is delimited to a two choice reaction time task.

2. The study is delimited to two ITIs, one of approximately 380 msec. (resulting in a serial self-paced task) and one of 1600 msec. (resulting in a discrete task).

3. The study is delimited to three stimulus-response (S-R) probabilities (.33, .55, .67).

Assumptions and Limitations

The following assumptions are made:

1. A developed RP can be stored in secondary memory (SM), and/or in primary memory (PM). For a RP to be put into SM it must have been in PM and reinforced a number of times. Any RP in PM can be consciously placed into selective attention (SA) when it is assumed that this response will be the next one called

upon.[1]

2. Selective attention has a maximum capacity of one engram.

3. A response program once put in SA remains there for a short time after the response is made.

4. When a certain response is required to be displayed, the retrieval process looks for this stored RP in SA first, then if not in SA, it searches PM, and finally, if not found there, in SM. This search process is performed serially, not simultaneously, in all three storage areas, and takes a finite time in each area.

The investigation is limited by:

1. The functioning of the CRT apparatus.

2. The accuracy of the timing equipment.

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[1] A this assumption is the same as Assumption 6 of Schutz(1972).

3. The sample size of 16 subjects.

Significance of the Study

At present there seems to be no adequate theoretical explanation advanced which accounts for the majority of experimental results reported on the repetition effect. Testable theories are needed in order to understand motor behaviour. One such theory of information processing and retrieval from motor memory is that proposed by Schutz (1972). The significance of this study is to add support, or reject, Schutz's model of motor memory retrieval, and further examine the ITI x Probability interaction on the repetition effect.

CHAPTER II

REVIEW OF THE LITERATURE AND ITS RELATIONSHIP TO SCHUTZ'S MODEL

Introduction

Choice reaction time experiments have been used extensively in the study of memory storage and retrieval. A choice reaction time experiment consists of a series of trials, on each of which the subject is presented a signal, chosen from a finite set of signals, and makes a response as soon as possible after the signal appears. There is a definite response for each alternative signal, which the subject has learned through practice, and the subject must make a response which corresponds to the signal. Although the subject knows approximately when the signal will come, he does not know which signal it will be and is, therefore, uncertain about which response he will have to make. By varying the number of stimuli or responses, or varying the probability of stimulus occurrence, the degree of uncertainty can be manipulated. In a typical experiment the signal might be presented by a set of light bulbs (pea-size) and the responses made by a set of keys mounted on micro-switches. When one of the bulbs lights up the subject presses the corresponding response key as quickly as possible. The time taken to do this includes not only the time to notice one of a certain set of changes in the environment, but also the time to decide which key should be pressed. "Choice-reaction time", therefore includes a "decision-time" (Laming, 1968).

A few basic qualitative facts about choice-reaction times were discovered early. Donders (1868, cited in Laming 1968) distinguished three types of reaction and suggested the subtraction method to determine time occupied in discriminating the signal and the time taken to choose the correct response. Donders work was based on the idea that the time between stimulus and response is occupied by a train of successive processes, or stages; each component process begins only when the preceeding one has ended. Mean reaction times from two different tasks are compared, where one task is thought to require all the stages of the first, plus an additional stage. The difference between mean RTs is taken to be an estimate of the mean duration of the interpolated stage.

There were relatively few choice reaction experiments prior to 1950, and for the most part those that were published had no theoretical orientation. Furthermore, the data of these studies was not presented in sufficient detail to be of use in discriminating among present day theories and thus pre 1950 research will not be discussed here. (see Woodworth, 1938, pp 298-339 for a comprehensive review). In the last twenty years however, there has been renewed interest in memory, reaction time and information processing, resulting in the isolation of numerous experimental variables which affect R.T., e.g.;

type, intensity, and frequency of stimuli, length of foreperiod, number of alternatives, S-R compatibility, inter-trial interval, level of motivation, anxiety, fatigue, amount of practice, type of S-R mapping, and the task complexity. To restrict the length of this review, only those studies dealing with the repetition effect, stimulus-response probability, and the effect of ITI will be discussed as well as the major probabilistic models and how they account for the repetition effect (see Smith, 1968a for a comprehensive review of the major theoretical positions). An attempt to relate the major findings of the relevant studies to Schutz's model of Motor Response Organization and Memory Retrieval will be made.

Probabilistic Models of Choice Reaction Times

The work of Hick (1952) and Hyman (1953) led to a theory in which human performance is compared to that of an ideal communication system. Hick used ten lamps and ten corresponding keys to measure mean reaction times to several series of equally probable signals. He fitted his data to the equation

$$t(n) = b \ln(n+1)$$

where $t(n)$ is the mean reaction time of the n equal probable signals. Hick concluded "the average amount of information extracted is proportional to the time taken to extract it, on the average." Hick's paper had a profound influence on subsequent research in choice-reaction time as he had come up with a quantitative equation to account for CRT, and he showed that choice-reaction time was determined not so much by the stimulus presented as by those stimuli which were not presented, but which might have been. Hick seemed to set the stage for a probabilistic theory of choice reaction time, but it was not until thirteen years later that Falmagne (1965) came up with a stochastic model for choice reaction time.

Falmagne's Model

Falmagne (1965) constructed a stochastic model and utilized a "state of preparation", to account for the earlier experimental results in the CRT studies (in particular the sequential phenomenon demonstrated by Bertelson (1961), which is discussed later in this review). If a particular stimulus in an experiment, say Sa (where Sa is the stimulus associated with light A) has recently occurred several times, the subject is likely to be prepared for it and will respond quickly when Sa appears again. But if some other signal, say Sb, has not appeared for a little while, the subject is less likely to be prepared for it and will respond more slowly when Sb is presented. So RT to a given signal is in part a function of the preceding signal. The subject will respond more quickly to those signals appearing more frequently and in this way will match his performance to the objective signal frequencies. The selective nature of preparation implies that if the level of preparation

(Ka) for Sa is very high then the level of preparation for other signals would tend to be low. The other basic postulate of Falmagne's model is the "all-or-nothing" character of preparation which is based on the assumption that the value of K (the level of preparation of a subject on the nth trial with respect to signal i) is a discrete rather than a continuous variable. In this case, either the subject would be prepared for the signal i or he would be unprepared. Falmagne (1965; 80) states:

> There are only those subjective impressions which would suggest a preference for all or nothing, such as: "One cannot think of two things at the same time ...". It seems fairly evident that, as is often the case, a model of the all-or-nothing type will prove too simple.

Thus only two states are considered in his model: the state prepared for stimulus i and the state not prepared for stimulus i. The subject may be prepared for more than one stimulus at trial n, or even not be prepared for any. However, if the subject is prepared for the stimulus presented, his RT is not exactly determined. The RT has a distribution function K(t) if the subject is prepared for the stimulus that is presented, and K(t) otherwise, with

$$E(t|K) < E(t|K)$$

Falmagne and Theois' Model

Falmagne and Theois (1968) proposed a five stage additive model for serial CRT tasks in which the basic assumption of a "state of preparation" similar to that of Falmagne (1965) was made. They assumed that when a stimulus is presented the template corresponding to that stimulus, templates corresponding to all possible stimuli being created and stored earlier, can be in a selective attention (SA) state, immediate memory (IM) state, or in a long term memory (LTM) state. They suggested a total response time (t) as:

$$t = t_1 + t_2 + t_3 + t_4 + t_5$$

where t_1 equals stimulus perception time and creation of the internal representation (IR)

t_2 equals time to check if IR matches the single template in SA

t_3 equals time to check if IR matches any template in IM

t_4 equals time to check if IR matches any template in LTM

t_5 equals response coordination and initiation time period

If a match occurs in step 2 (correct response is in SA) then stages 3 and 4 are skipped. If a match occurs in step 3 (correct response template is in IM) then stage 4 is skipped. Since each step requires finite time, it follows that RT to a stimulus A which has response A in SA is fastest, whereas RT to a stimulus which does not have response A in either SA or IM is slowest. Falmagne and Theois propose that the probability of a template being in any one of the three states is governed by a first order Markov process dependent upon the immediately preceding stimuli presented. The average CRT is the weighted sum (weighted by the probability of a stimulus being presented) of the three distributions of time where:

$$t_a = t_1 + t_2 + t_5$$
$$t_b = t_1 + t_2 + t_3 + t_5$$
$$t_c = t_1 + t_2 + t_3 + t_4 + t_5$$

and

$K(t_a)$ is the distribution of RT's (t_a) if the required response program is in SA,

$K(t_b)$ is the distribution of RT's (t_b) if the required response program is in IM, and

$K(t_c)$ is the distribution of RT's (t_c) if the required response program is neither in SA nor IM

where:

$$E(K(t_a)) < E(K(t_b)) < E(K(t_c)).$$

Now, since E(RT) is a weighted function of the $K(t_{i's})$, average response time should be fastest if the correct response is in SA most of the time.

Schutz's Model

Schutz (1972) proposed a theoretical deductive model which deals primarily with the organization and retrieval from memory of the responses. Although Schutz states that "the theory proposed here is not an adaption of any one particular existing theory, but rather is a combination of relevant ideas from many theories in conjunction with deductions from empirical findings", a profound influence of Falmagne (1965) and Falmagne and Theois (1968) can be noted. Schutz considers his model in terms of organization, the memory storage area and, the memory search processes and response retrieval.

<u>Organization of a Response Program</u> The theory proposed is a response-oriented one, as shown by Schutz's assumption that most of the variability in response latency can be accounted for by the retrieval and organization of the memory engram. This assumption was not totally supported, and in Revision One Schutz suggests that the word "most" in the phrase above should be changed to "a considerable portion". The basic assumption of the theory is "there are a number of stages involved in information processing and response organization in a CRT task and that these stages act independently of each other with a total CRT being the summation of the time for each seperate stage". This is the same as the basic assumption of Falmagne and Theois (1968).

<u>Memory Storage Areas</u> Schutz proposed that the search and retrieval process examines up to three memory storage areas. The first one is termed selective attention (SA) which has a capacity of on engram, either an event very recently experienced, or a response expected to be called upon in the

immediate future. Schutz originally assumed that SA is non empty on every trial, but in Revision One hypothesized that it need not be non-empty. A second area of storage, easily accessible but of limited capacity (somewhere between five and ten programs, the exact number probably being a function of the length of the programs) is termed primary memory (PM). The third possible storage place, secondary memory (SM), is conceived of as a memory bank in which there are stored developed programs. Secondary memory was not examined by Schutz and will not be discussed further (see Norman, 1969, for a more detailed account of the memory stores).

<u>Memory Search Process</u> The memory search process for a specific program in PM is assumed to be a serial exhaustive search (as suggested by Sternberg, 1966). The need for this assumption is not clear, however, and was not experimentally tested. The search of SM was conceived of as being something other than a serial exhaustive search, but this was not of concern to this study which dealt only with SA and IM.

<u>Response Retrieval in a CRT Task</u> In a CRT task the information processing and response retrieval mechanisms are assumed to be modelled as in Figure 1. The time required to perform the steps shown in Figure 1 can be represented as

$$CRT = t_1 + t_2 + t_3 + t_4 + t_5$$

The model is similar to that proposed by Falmagne and Theois (1968) with each stage taking a finite amount of time and the summation of the time taken for each stage is the CRT. The time taken to perceive the stimulus, t_1, is considered to be a constant for any given subject. Search times t_2 and t_3 are the stimulus categorization stage (t_2) where the stimuli is classified into one of the possible stimuli, and the response selection stage (t_3), which pairs the appropriate RP to the given stimulus. The reading out of the required response program is represented as t_4, and the time from the release of the program until movement is initiated is represented by t_5. Much of the experimental evidence in CRT studies suggests it is the response search and release mechanisms which account for differences in RT's under different conditions. The memory search process always examines the contents of SA first. If the required response program (RP) is not the one stored in SA, the process then conducts an exhaustive search through PM and, failing to locate the desired RP, it then begins a selective search through parts of SM. Schutz postulated that a response B will be in SA with probability P and PM with probability 1-P (this is true only when the responses are frequent and few enough to all be retained in PM). The variables governing the probability of a response being in SA are the probability of the stimulus, P(a), sequential effects of the presentation of stimuli, and the degree of task complexity. Also inherent in Schutz's assumptions, but not experimentally tested, is the

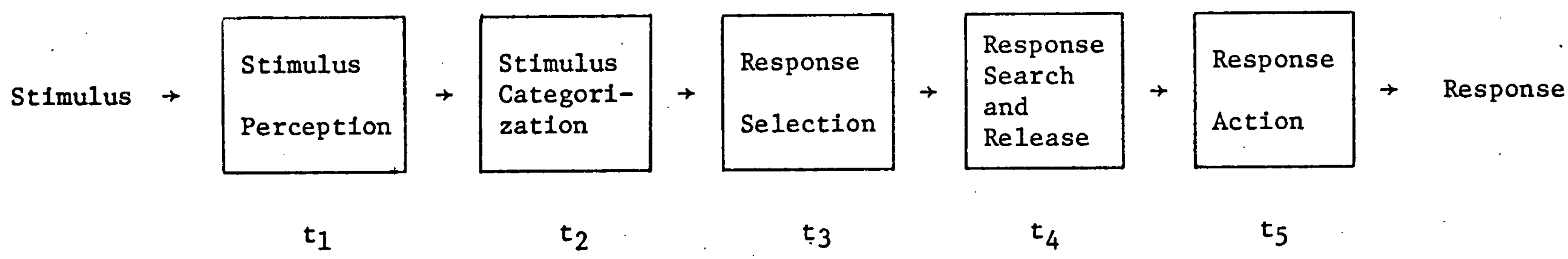

FIGURE 1 Schutz's Model of Information Processing and Response Retrieval Mechanisms in a CRT Task.

effect of the ITI. A review of selective studies on the sequential effects (repetition effect), probability of the stimulus, and ITI follows. See Ryan, 1971 for a review of other experimental variables affecting CRT.

Repetition Effects

Bertelson (1961, 1963) demonstrated that in a serial self-paced choice reaction task, reaction times (RT) to repeated signals, that is to a signal identical to the immediately preceding one, are shorter that RT's to non-repeated signals, provided that the time-lag separating the onset of each signal from the end of the previous response is short. He termed this the repetition effect (RE). Others to support this finding in a two choice self-paced condition were Williams (1966), Hale (1967, 1969), Smith (1968b), Schvaneveldt and Chase (1969), Kornblum (1969), and Kirby (1972). In contrast to the results from serial RT tasks, experiments using a discrete two choice RT paradigm specifically found "negative recency" or alternation effect (AE) (e.g. Hyman, 1953; Williams, 1966; Moss, et al., 1967; Remington,1970). Attempts to explain the repetition effect by Bertelson (1963) and alternation effect by Williams (1966) have both assumed that they are primarily due only to the immediately preceding event. However, Remington (1969) has shown that, for the repetition effect at least, events two, three, and four back in the series can also contribute to the difference between repetitions and alternations. The major distinction between those finding RE and those finding AE in CRT studies is inter-trial interval.

Inter-trial Interval

Bertelson (1961) in his initial finding of the RE stated it to be found when the time from the last response to the presentation of the next stimulus was short. Thus, there is a distinction between a serial self-paced task (ITI < 500 msec.) where there are reported RE; and discrete tasks, where there are reported AE's.

Schutz's Model and ITI

Schutz accounts for the empirical finding that CRT's are shorter for repeated S-R pairs than for changed S-R pairs in self-paced serial CRT tasks by the following theoretical explanation:

> In a self-paced serial CRT task the stimulus for trial n+1 occurs so quickly after the response made on trial n, that a subject rarely prepares himself for any particular stimulus or response.
> .... it is possible that when a response is found, whether it is in SA, PM, or SM, it must be put in SA before it can be discharged. It could also be hypothesized that immediately following the elicitation of a response, the RP is put into SA so it is available for comparison with various visual and kinesthetic feedback messages. In either case, the RP of the immediately preceding response is in SA for a short interval of time following the discharge of that response. With very short ISI (ITI) the RP is still in SA on presentation of the next stimulus, and, if it is a

> repeated S-R pair, the correct RP will be in SA, thus resulting in a shorter search time.

Schutz accounts for the empirical findings that CRT's are longer for repeated S-R pairs than for changed S-R pairs in a discrete task, with the following theoretical explanation:

> In a discrete CRT task the subject has sufficient time between trials to prepare himself for the next S-R pair. Although the probability of occurrence of any stimulus is independent of the previous one, it is theorized that the subjective probabilities formulated by the subject do not exhibit this independence. (This was found to be the case by Jarvick, 1951, who demonstrated the well known 'gamblers fallacy').[1] If response A is required on trial n the subject assumes that the probability of B being required on trial n+1 is higher than it would be if B had been required on trial n. Therefore, given equal average probabilities of response requirements, a subject will, on the average, be more likely to put into SA that RP not retrieved on the previous trial.

Stimulus and Response Probability

It has been well established that in a CRT task with compatible S-R pairs of equal complexity, RT is inversely related to stimulus-response occurrence (e.g. Bertelson, 1961; Krinchick, 1963; Bertelson and Barzeele, 1965; Kornblum, 1967; Hannes, Suttin and Subin, 1968; Laming, 1969; Sanders, 1970; Umilta, et al., 1972; Geller, Whitman, and Post, 1973). However, it is not clear whether the stimulus probability or response

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[1] Phrase in parenthesis is my own

probability is the determinant of this effect. Some researchers suggest that response frequency is the major determinant (e.g. Schlesinger, 1964, LaBerge and Tweedy, 1964; Bertelson, 1965; Bertelson and Tisseyre, 1966; Biederman and Zachery, 1970; Hawkins and Hosking, 1969; Blackman, 1972), whereas Barber and Folkard (1972) showed both stimulus probability and response probability affect CRT independently. However, as P(s) equals P(r) in this study the above is not of paramount importance. Correct prediction of the S-R pair is used by some (Hale, 1967; Keele, 1969) to account for the effect of probability while others (Geller and Pitz, 1970; Geller, et al., 1971) suggest probability of the S-R pair has an effect independent of that of correct predictions. As Geller, Whitman and Post (1972) point out, the amount of probability information given Ss in a choice RT task has probably never been considered to be an important determinant of response latency. In fact some investigators did not report whether or not they informed Ss of the frequency imbalance (e.g. LaBerge and Tweedy, 1964; Kanarick, 1966; Hawkins and Friedin, 1972).

Schutz's Model and Response Probability

Schutz's model accounts for the effects of S-R probability by means of the response probability. In fact his basic assumption that a considerable part of the variability in response latency can be accounted for by the retrieval and organization of memory response engrams. Schutz accounts for the empirical finding that CRT increases with a decrease in the probability of occurrence of a S-R pair, with the following theoretical explanation:

> The greater the probability of a response, the greater the likelihood of the required RP being in SA and consequently the shorter the search time.

Summary

In summary the literature reviewed supports the following in respect to RE in CRT studies:

1. In a discrete CRT task there is a negative repetition effect.

2. In a serial CRT task there is a repetition effect.

3. RT is inversely related to stimulus-response occurrence.

All of the above are accounted for by Schutz's model, which leads to the theoretical account of the hypotheses of this study.

Theoretical Rationale for Hypotheses

The three hypotheses, as stated in Chapter I, are logical deductions, based on the assumptions of Schutz. The rationale for each hypothesis is as follows:

Hypothesis 1 states that in the serial self-paced task there is a repetition effect (which asymptotes after one repetition), while in the discrete task there is a negative repetition effect (which does not asypmtote at one repetition).

The model accounts for the RE in a serial self-paced task by hypothesizing that the previous response is in SA for a short interval of time following the discharge of the response. Thus the search time is at a minimum. A sequence of repeated events should therefor all have RTs form the same distribution. The negative repetition effect (AE) in the discrete CRT task is explained by the subject, who, on the average, in preparing for the next stimulus, is more likely to put into SA that RP not retrieved on the previous trial. Thus some of the RTs are from the distribution of RTs prepared for, and some from the distribution of RTs not prepared for. After a single repetition the subject is probably more likely to prepare for the alternate effect, thus in responding to a second repetition even more of the times are drawn from the slower, unprepared for distribution of times from PM. Consequently there is no asymptote at one repetition.

<u>Hypothesis</u> <u>2</u> states that the probability of occurrence has no effect in the serial self-paced task.

Since the previous engram is already in SA, RT should be at a minimum, and changing the probability of the S-R pair should have no effect.

<u>Hypothesis</u> <u>3</u> states that the low probability of occurrence in the discrete case results in the longest RL, while the high probability results in the shortest RL.

This hypothesis is explained by the "state of preparation" of the subject, the greater the likelihood of the required RP being in SA and consequently the shorter the search time.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Sixteen subjects completed 480 RT's under each of four experimental conditions. Due to technical difficulties with the apparatus, which is discussed further below, two subjects were unable to complete the experimental condition on the fourth day. There were ten female and six male subjects, all students or staff at the University of British Columbia. Subjects ranged from eighteen to thirty-two years of age, with a mean age of 22.5 years. All subjects were right-handed.

Each subject was to complete the four experimental condition on four consecutive days, each person coming in at approximately the same time during the day. Two subjects were unable to come in on the fourth test day, and were consequently tested twice at two different sessions on the third day. On the fourth day, due to equipment failure, no datum was obtained on three subjects, these subjects were subsequently tested after a lapse of three days. Insufficient data on two of these three subjects was obtained, thus two of the original sixteen subjects were eliminated from the analysis.

Apparatus

The apparatus used in this experiment was a reaction time console which consisted of an operator's console, and the subjects's console.

<u>Subject's Console</u>. The console consisted of a 31 cm. box, with stimulus lights, (called stimulus a or b), 6.3 volts, 0.15 amps each, and two response keys (A and B), placed approximately 6 cm. below the corresponding light. Response keys had to be depressed approximately 1.5 mm., requiring a movement time of approximately 44 msec. to contact the switch and stop the clock. On the side of the console a toggle switch allowed the experimenter to control ITI. In the up position (discrete task), the ITI was approximately 1837 msec. at the left light and approximately 1436 msec. at the right light. While in the down position (serial self-paced task), the ITI was approximately 393 msec. at the left light and 377 msec. at the right light. All differences in ITI between the stimulus a and b were attributable to the inexactness of the capacitors, since the circuits were identical for both the right and left light. A white noise generator presented noise to the subject via earphones to mask extraneous noise. The subject's console was separated from the experimenter's console by approximately four feet, with a curtain between the two.

<u>Experimenter's Console</u>. The experimenter's console consisted of a programmer, a reaction time interface and a digital printer. The programmer, (manufactured by Ralph Gebrands Company, U.S.A., model PPR-1) was designed to close the circuits so that either light a or light b came on in a preprogrammed sequence. The devise operated by means of a trigger, which, when a 8 mm. film was read through the the trigger, would open one switch if there was no hole in the film at that point, or open the other if there was a hole in the film. The film advanced approximately 2 mm. each time the contacts were closed, so that a sequence of trials could be built into the film. Four film strips were constructed, two (strip 1 and 2) to result in equal number of left and right S-R pairs, strip 3 was constructed to result in twice as many S-R pairs on the left and strip 4 was constructed to result in twice as many S-R pairs on the right. The Reaction Time Interface, (manufactured by Canadian Dynamics Instrument Division), and the Digital Printer, manufactured by United Systems Corporation were wired so as to time in milliseconds the onset of the stimulus light on the subject's console till the depression of the response key. The device was wired so that the time from the a-A S-R pair was printed on channel one and the time from the b-b pair was printed on channel two, except that each RT for time n was printed on the channel that the RT for time n-1 belonged. The system did not allow for checks if the inappropriate response key was depressed, (i.e. response B to stimulus a, or response A to stimulus b), but gave a double

printout if the response key was depressed before the stimulus light went on.

Response task

Subjects were seated in front of the apparatus. One of the film strips, predetermined by the condition the subject was serving in, was mounted in the film reader and the equipment readied. The instructions as appear in Appendix B were then read. The subject, informed of the condition he was serving in that day, then assumed the ready position by placing his index finger of both the right and left hand on the corresponding response key. The white noise was then turned on and directions ready, start, audible over the noise, were given. The subject was asked to respond to the stimuli as quickly as possible by depressing the corresponding response key. In the serial self-paced task the stimulus light came on approximately 380 msec. after the response to the previous stimulus, while in the discrete task there was an ITI of approximately 1600 msec.. Five blocks of 96 S-R sets were presented, with a 30 sec. rest between blocks. The average time taken for each condition was 12 minutes for the serial self-paced task, and 23 minutes for the discrete task.

First day sessions were preceded by a practice session of 50 trials in the corresponding condition, while on subsequent days only 20 trials were utilized as a practice session. The sequence of stimuli presentation for each of the 5 blocks of 96 trials were predetermined and unknown to the subjects, however the subjects were told the pre-set probabilities of each stimulus light coming on. Due to the functioning of the programmer, trials were slightly different for each subject, and were unknown to the experimenter until the paper tape of times was produced. The expected number and actual number of experimental variables is shown in Table I.

Experimental Conditions

Four experimental conditions were tested which gave rise to 24 measures of the dependent variable for each subject. In each condition there were two stimuli (a or b) and an associated response (A or B) to each. For eight of the subjects, chosen randomly, stimulus a was associated with the left key, and stimulus b with the right key, for the remaining eight subjects this procedure was reversed. The four conditions were assigned to four columns (days) of a Latin Square, repeated four times, thus the conditions were latinized over days, the specific ordering of conditions being as given in Table II, Appendix B. Subjects were assigned randomly to one of four rows of the Latin Square, with the constraint that only four people could be

TABLE I

Expected and Actual Number of Valid S-R Pairs

Within Each Block of 480 Trials

	Prob	AL	RE	DRE	MORE	TOTAL
expected	.33	107	36	11	5	159
ctual ITI	.33	94.9	37.1	10.2	6.8	146.9
ctual ITI	.33	90.7	28.6	11.5	4.8	144.8
ercent of expected		86.7%	91.2%	98.6%	116.0%	91.7%
expected	.50	120	60	30	30	240
ctual ITI	.50	92.9	53.1	24.7	14.7	185.4
ctual ITI	.50	84.2	49.5	23.3	13.1	170.0
ercent of expected		72.8%	85.5%	80.0%	46.3%	74.0%
expected	.67	107	70	47	95	319
ctual ITI	.67	87.5	49.6	29.4	40.1	206.6
ctual ITI	.67	92.2	51.3	30.1	37.9	211.5
ercent of expected		83.9%	72.0%	63.3%	41.1%	65.5%

assigned to any one row. The conditions were:

Condition one: 480 trials at short ITI, P(a)=.33, P(b)=.67

Condition two: 480 trials at short ITI, P(a)=.5, P(b)=.5

Condition three: 480 trials at long ITI, P(a)=.33, P(b)=.67

Condition four: 480 trials at long ITI, P(a)=.5, P(b)=.5

Within each of the four conditions, S-R pairs were separated into either alternations (AE), repetitions (RE), double repetitions (DRE), more than a double repetition, or error. The last two were discarded in the analysis. Median reaction time of each subject (S) in each cell was used as the dependent variable. Each condition then gave rise to six measures of the dependent variable for each subject. That is, median reaction time for both a-A and b-B for AE, RE, and DRE. Since in conditions 2 and 4 P(a) = P(b) = .5 the mean of the medians for a-A and b-B within the condition was used as the measure of the dependent variable, thereby reducing the number of dependent variables by 6. Thus the dependent variable was based on 960 trials in Condition 2 and 4, rather than 480 trials as in Conditions 1 and 3.

Experimental Design

The experimental design gives rise to six measures of the dependent variable in each condition. The six levels of the dependent variable are: (1) alternation from A to B; (2) single repetition of A; (3) double repetition of A; (4) alternation from B to A; (5) single repetition from B; (6) double repetition of B. In conditions 1 and 3 stimulus a had P(a) = .33 while stimulus b had P(b) = .67; whereas in Conditions 2 and 4 P(a) = P(b) = .5. Thus in the analysis of the data, the experimental design can be treated as a 2 x 3 x 3 factorial with repeated measures on all three factors. The factors and levels are then inter-trial interval (ITI) with two levels, probability (P) with three levels, and response (R) with 3 levels. The statistical design is diagrammed in Figure 2. A 3-way analysis of variance with repeated measures on all three factors was performed. Post hoc comparisons utilizing orthogonal polynomials followed a significant F. In addition the following preplanned comparisons were made to test the specific hypothesis.

Test of Hypothesis 1

Hypothesis one states that in the serial task there is a repetition effect (asymptoting after one repetition), while on the discrete task there is a negative repetition effect. This would be indicated by a significant inter-trial interval (ITI) by condition (R) interaction.

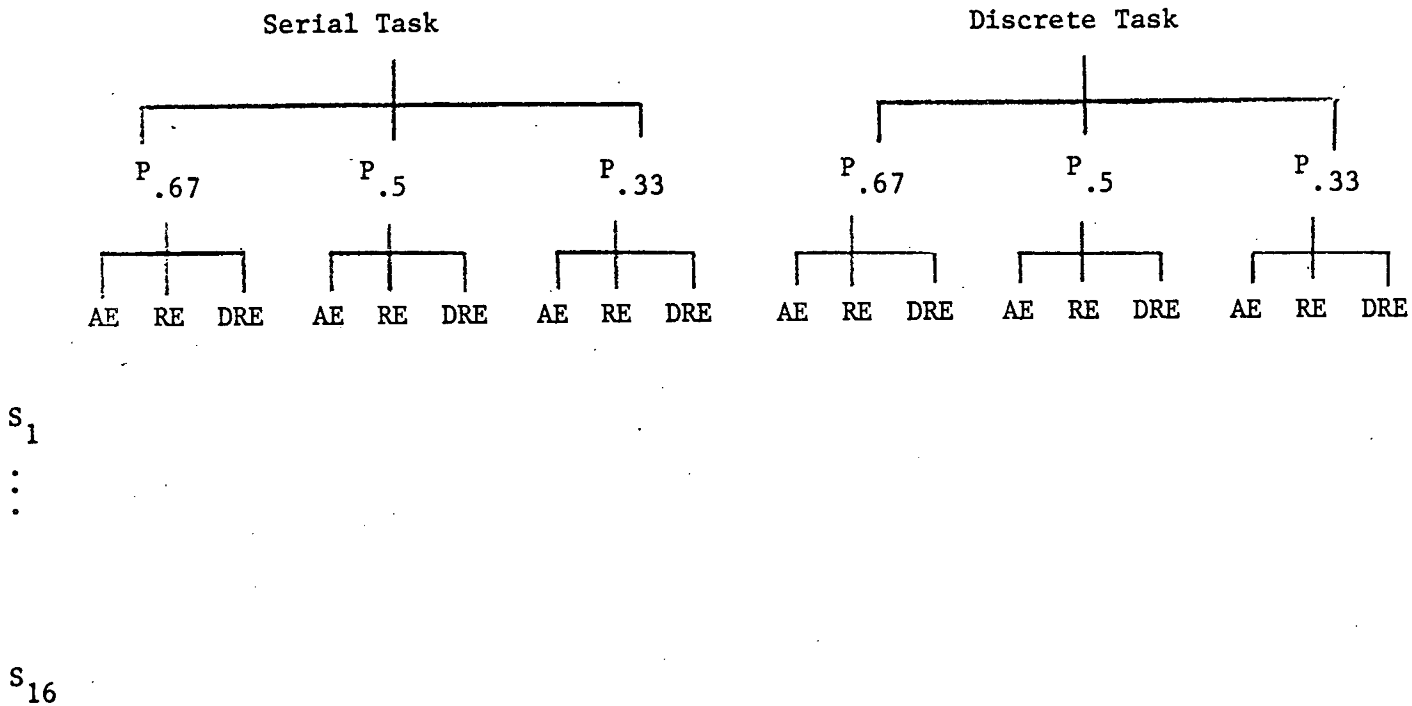


FIGURE 2: Schematic Representation of Experimental Design

Test of Hypothesis 2

Hypothesis 2 states that probability of occurrence of the S-R pair has no effect in the serial self-paced task.

This would be tested by pre-planned orthogonal contrasts following a significant P effect. The specific weighting coefficients for the pre-planned test among probability means are:

Serial Task

	$P_{.67}$	$P_{.50}$	$P_{.33}$
(1)	1	0	-1
(2)	1	-2	1

The particular weighting coefficients chosen are those for trend, used to determine if a linear or quadratic trend exists. This is due to the fact that if there is an effect of probability it would most likely be a linear trend, thus these weighting coefficients should allow for the most power in the statistical test.

Non rejection of the null hypothesis would lend support for the retention of Hypothesis 2.

Test of Hypothesis 3

Hypothesis 3 states that probability of occurrence of the S-R pair has an effect in the discrete task, specifically that the low probability results in the longest RL, while the high probability results in the shortest RL. This would be tested by a trend analysis on probability within the discrete task, using the following orthogonal weighting coefficients:

Discrete Task

	$P_{.67}$	$P_{.50}$	$P_{.33}$
(1)	1	0	1
(2)	1	-2	1

General Test of Hypothesis 2 and 3

To further examine the effects of probability on RT, the ITI x P(linear) was utilized. Although this contrast was not orthogonal to the specific tests conducted for Hypothesis 2 and 3, it was thought useful in explaining the predicted effects. That is, the linear effect of probability in the discrete task should be greater than the linear component of probability in the serial task.

Data Analysis

Upon succesful completion of data collection, the times from the paper tape were coded on to FORTRAN coding sheets, with times from channel 1 being recorded as positive times, times from channel 2 recorded as the actual times x -1, and inappropriate or error times were recorded as 999. This was done in order that the computer program would recognize which channel the time came from. A computer program, READATA, was written (see Appendix C) to read the data and separate it into the eight effects for each subject. That is, each subjects' data was rewritten subject by subject in fields on the computer output as follows:

field 1 alternation from left to right
field 2 alternation from right to left
field 3 a single repetition of the right light
field 4 a single repetition of the left light
field 5 a double repetition of the right light
field 6 a double repetition of the left light
field 7 more than a double repetition of the right light
field 8 more than a double repetition of the left light

Each subjects' set of data from the output of READATA, was then analyzed by means of the UCLA BIOMEDICAL PROGRAMME BMD P2D, a descriptive statistics package, to give the frequency, median and other measures. The median of each of the first 6 effects above gave the measures of the dependent variable for each subject in each of the four experimental conditions. A computer programme FREQCOUNT (see Appendix C) was used to count the number of valid times for each subject within each trial. Using the median of each subjects trials, in each condition, 24 measures of the dependent variable (RT) were obtained for each subject. This data was then tabled (Subjects (n=14) by effect within condition (6 x 4)). However, since in conditions 2 and 4, P(a) = P(b) = .5, the mean of the median for each of the AE, RE, and DRE conditions was taken for both P(a) and P(b), using the computer program MEANMED (see Appendix C). Thus the number of measures of the dependent variable was reduced to 18 per subject. Two of the subjects' data was eliminated from the analysis due to too many missing values. Thus the original data of 480 trials by 4 days by 16 subjects was reduced to 18 measures of the dependent variable by 14 subjects for the statistical analysis. The computer programme BMD P2V, was used to give a repeated measures analysis of variance with an orthogonal breakdown of each source of variation to test for trend.

Error

Malfunctions of the testing apparatus necessitates a section be devoted to considerations which might have contributed to experimental error.

<u>Film Strip Error</u>. The equipment was designed to present a prior determined probabilistic sequence of two choice S-R trials. However, because of the design of the apparatus, the sequence of trials varied slightly from condition to condition. That is, the same film strip used to programme a series of S-R trials, resulted in slightly different series, each time it was used. This was due to the fact that it was impractical to attempt to start the series at exactly the same position on the film strip, and also the fact that the film reader didn't advance exactly the same amount each time. Thus, film strip 1 and 2, which should have resulted in exactly a 50:50 proportion of stimulus light a to b, in some cases was in a 46:54 proportion. Furthermore, it was impossible to generate the film strip as intended, matching a psuedo base random generation, but rather the film strip was made on a trial and error basis. That is, holes were punched in the film strip at random and the strip was adjusted and rechecked. This procedure was continued until the desired proportion of each stimulus resulted. In the actual experiment, the sequence could not be determined until the printer tape with the times listed was examined. Even this proved to be unsatisfactory, due to printer errors.

Printer Errors. The circuit was wired to print the reaction time from the left side S-R pair on channel 1 and the RT from the right side S-R pair on channel 2. However, there was a built-in lag which resulted in trial n being recorded on the channel trial n-1 belonged. Thus in order to know to which experimental condition trial n belonged, it was necessary to go back until the previous alternation. The k trials until the first alternation therefore, provided no information.

Due to the number of printer errors, the actual number of presentations of each stimulus light was impossible to determine, since it was not recorded during the actual experiment. It was assumed, and there were no reasons to suggest otherwise, that the printer errors occurred randomly. Thus, while they resulted in a different number of trials per person in the calculation of the dependent variable in each experimental condition, the median of the valid responses is still considered to be the best estimate of true RT. The resultant effect should at most be an increase in variability of the random variable (subjects, subject's by experimental conditions), thereby reducing the power of the statistical tests applied.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The results of the descriptive analysis for each subject's session (obtained from BMD:P2D) are given in Table II, Appendix B. Table I below shows the expected number and actual number of valid measures obtained in each experimental session. The expected numbers were obtained by a Monte Carlo simulation, by means of the computer programmes SIM (see Appendix C) and UBC SIMCORT. The mean error rate calculated as the mean number of invalid responses per trial is 26.3%, considerably higher than reported in the literature (Remington, 1973). This is attributed to equipment malfunctions (as previously discussed) as well as due to errors made by the subjects (Ss).

A table of means within each cell, collapsed over Ss, is given in Table II below. Table IIa gives the means within the serial task, Table IIb gives means within the discrete task, and Table IV the means collapsed over ITI. The means are illustrated in Figure 3, collapsed over Ss, and R (to illustrate the main effect of P and the ITI x P interaction) and in Figure 4 collapsed over Ss and P (to illustrate main effects of R and ITI

TABLE IIA

Table of Means for ITI

	P	P	P	P
Condition 1	357.1	354.6	373.7	361.8
Condition 2	347.3	333.4	369.0	350.0
Condition 3	333.3	329.9	364.4	342.6
Cond	345.9	339.3	369.0	351.4

TABLE IIB

Table of Means for ITI

	P	P	P	P
Condition 1	332.0	355.0	358.1	348.4
Condition 2	335.9	347.8	353.9	345.9
Condition 3	327.6	338.4	349.5	338.5
Cond	331.8	347.1	353.9	344.3

TABLE IIC

Table of Means Collapsed over ITI

	P	P	P	P
Condition 1	344.6	354.8	365.9	355.1
Condition 2	341.6	340.6	361.5	347.9
Condition 3	330.5	334.2	356.9	340.5
Cond	338.9	343.2	361.5	347.8

FIGURE 3

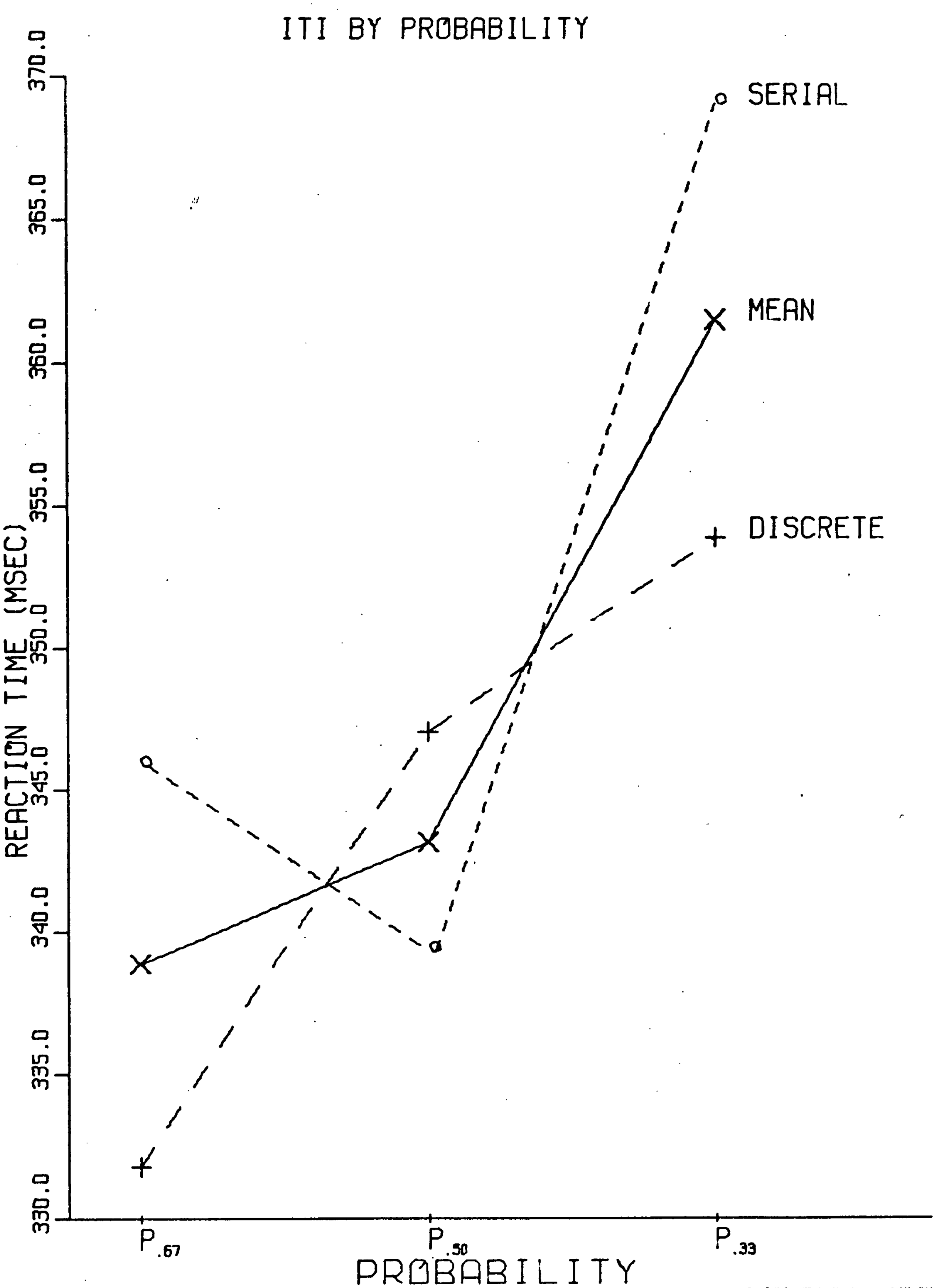
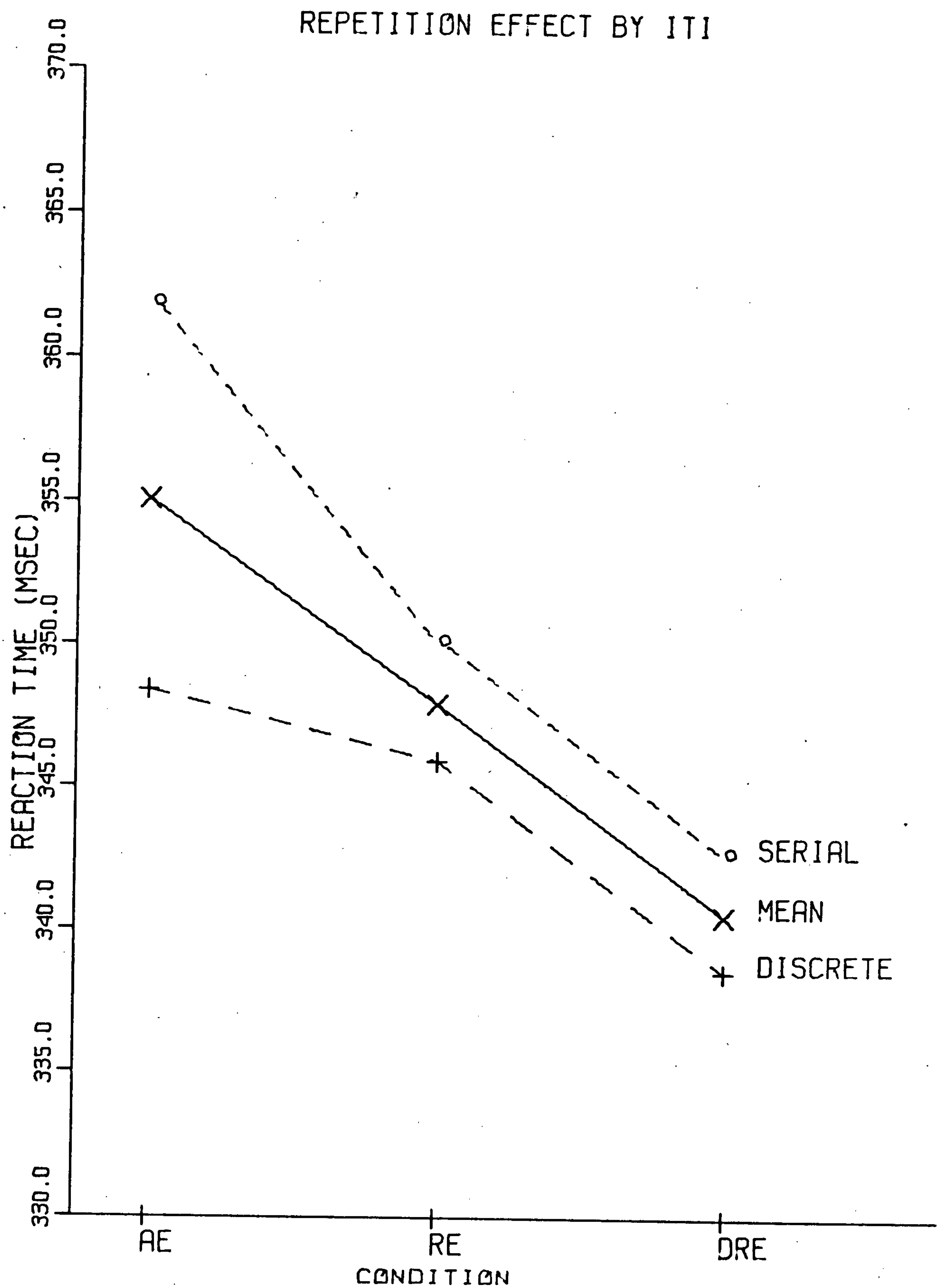

ITI BY PROBABILITY
REACTION TIME (MSEC)
370.0
365.0
360.0
355.0
350.0
345.0
340.0
335.0
330.0
SERIAL
MEAN
DISCRETE
P.67
P.50
P.33
PROBABILITY

FIGURE 4


REPETITION EFFECT BY ITI
REACTION TIME (MSEC)
370.0
365.0
360.0
355.0
350.0
345.0
340.0
335.0
330.0
AE
RE
DRE
CONDITION
SERIAL
MEAN
DISCRETE

X R interaction). The three conditions are, an alternation (AE), a repetition (RE), and double repetition (DRE).

The dependent variable (RT) was analyzed using analysis of variance in a 2 x 3 x 3 (ITI x P x R) repeated measures on all factors design (Keppel, 1973: 460). The results are presented in Table III below. The analysis of variance shows only the main effects of probability (P) ($F_{2,26}$ = 4.86, $p<.05$) and condition (R) ($F_{2,26}$ =8.65, $p<.01$) as being significant. Most of the variance in the probability main effect was accounted for by the linear trend of RT over probability.

<u>Test of Hypothesis 1</u> The non-significant ITI x R ($F_{2,26}$ =1.39, $p>.2$) interaction gave no support for Hypothesis 1, which predicted an interacting effect.

<u>Test of Hypothesis 2</u> the statistical test applied to Hypothesis 2 was a trend analysis of the means (over conditions) of each probability within the serial task (see Table IV below). The linear component ($F_{1,26}$ =4.43, $p<.05$) was significant while the quadratic trend failed to reach significance. ($F_{1,26}$ <1). Thus no support of Hypothesis 2 was shown, rather a significant linear trend of increasing RT with decreasing probability in the serial task.

TABLE III

A 2X3X3 REPEATED MEASURES ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	MEAN SQUARE	F	P
SUBJECTS (S)	13	18674.13		
INTER-TRIAL INTERVAL (ITI)	1	3228.59	1.02	>.05
S X ITI	13	3173.21		
PROBABILITY (P)	2	12062.90	4.86	<.05
S X P	26	2481.07		
CONDITION (R)	2	4441.63	8.66	<.001
S X R	26	512.92		
ITI X P	2	3524.37	2.15	>.05
S X ITI X P	26	1637.02		
ITI X R	2	613.07	1.39	>.05
S X ITI X R	26	440.61		
P X R	4	389.51	<1	>.05
S X P X R	52	399.90		
ITI X P X R	4	211.82	<1	>.05
S X ITI X P X R	52	482.63		

TABLE IV

SUMMARY OF THE TREND ANALYSIS FOR PROBABILITY IN THE SERIAL TASK

OURCE OF VARIATION	DF	MEAN SQUARE	F	P
P WITHIN ITI LINEAR	1	33767.68	4.43	<.05
ERROR		849.70		
P WITHIN ITI QUADRATIC	1	3709.88	<1	>.05
ERROR		4112.44		

TABLE V

SUMMARY OF THE TREND ANALYSIS FOR PROBABILITY IN THE DISCRETE TASK

OURCE OF VARIATION	DF	MEAN SQUARE	F	P
P WITHIN ITI LINEAR	1	3418.87	4.02	>.05
ERROR		849.70		
P WITHIN ITI QUADRATIC	1	202.3	<1	>.05
ERROR		4112.44		

Test of Hypothesis 3 The test applied to Hypothesis 3 was a trend analysis of the means (over conditions) of each probability in the discrete task. Both the linear trend ($F_{1,26}$ = 3.20, p>.05) and the quadratic trend ($F_{1,26}$ < 1) were non-significant (see Table V). Thus no support was offered for acceptance of Hypothesis 2.

General Test of Hypothesis 2 and 3 The joint effects of the second hypothesis were tested by means of the ITI x P interaction. Non-significance of this interaction suggested that at least one of the hypothesis was not supported. The ITI x P interaction was non-significant ($F_{1,26}$ =2.15, p<.05) and thus supported the previous tests.

Discussion

Error Rate

Inspection of the descriptive analysis suggested no anomalies other than the large number of invalid times. Inspection of Table I Appendix B, seemed to indicate the invalid times occurred randomly throughout each condition, while from inspection of the number of scores for each condition, for each subject, for each day, (see Table III Appendix B) it can be seen that there were considerably more invalid scores on the last test day. This is attributable to the progressive wearing of the relay switches, which became less dependable after continued usage. It was impossible to differentiate between an inapropriate response (responding with B to stimulus A or visa-versa, or responding prior to stimulus presentation) and equipment malfunction. Hence the reported mean error rate of 26.3% is made up of both errors and equipment malfunctions. The S's error rate is assumed to be approximately 5%, which is at the high end of reported error rates in CRT studies (Remington, 1973).

At both P = .5 and P = .67 there were significantly fewer (44.1% and 69.2% fewer respectively) actual than expected S-R pairs of the more than double repetitions kind. This could be explained by the fact that the film strip was not generated randomly but rather on a trial and error basis, and also to equipment malfunctions.

Probability

The main effect of P was significant in the overall Analysis of Variance. Inspection of Figure 3 reveals a trend of increasing RT with decreasing probability of occurrence of the S-R pair. This is in general agreement with the literature (Kornblum, 1967) and not unexpected.

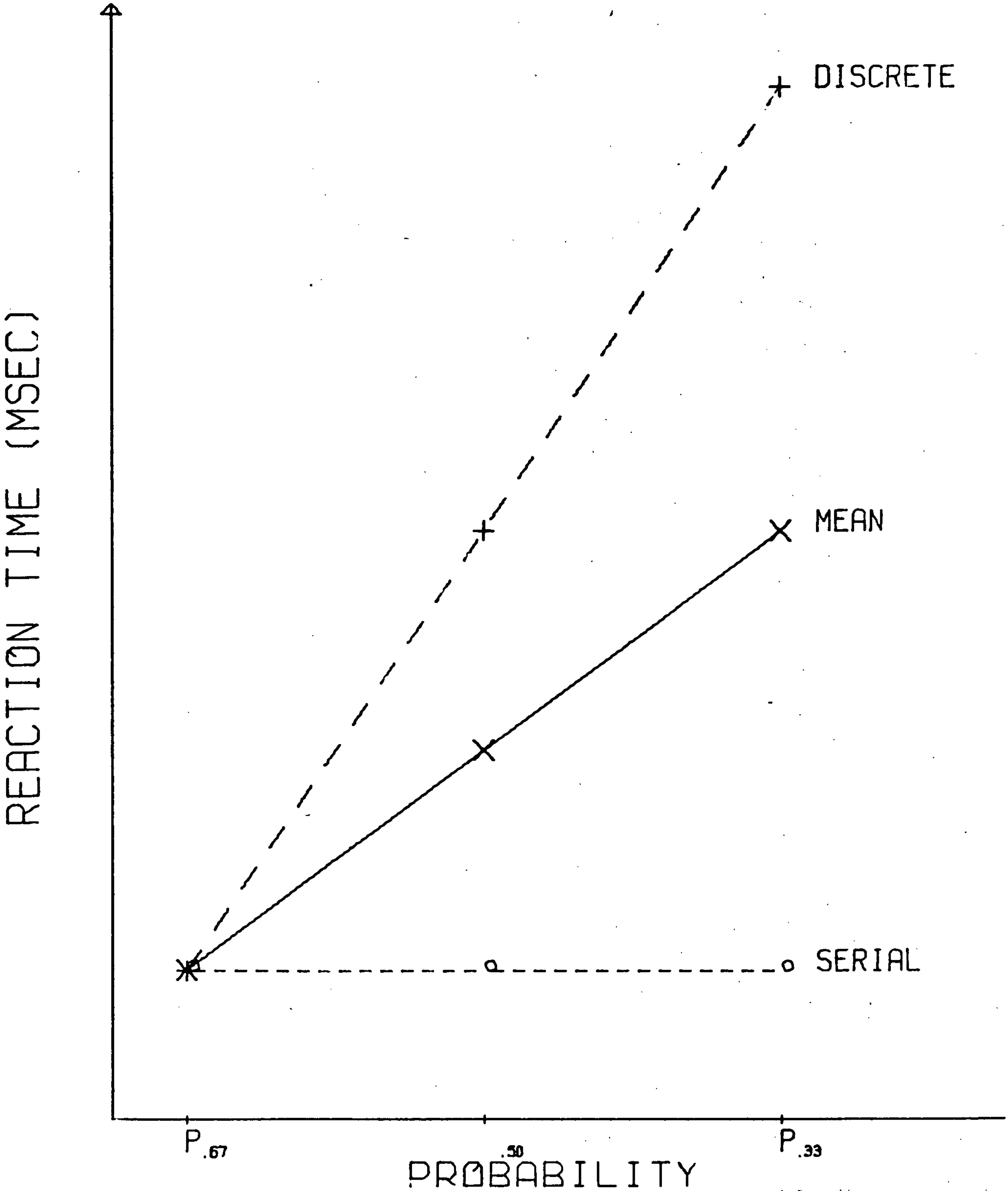
The pre-planned orthogonal contrasts to test the specific hypothesis showed statistical significance in the linear component of the trend of probability within the serial task. Thus Hypothesis 2 is rejected. Rather, the predicted effect of probability (see Figure 5 below) resulting in decreasing RT in the discrete task was evident in the serial task.

The pre-planned contrasts for trend of probability within the discrete task failed to reach significance. That is, there was no statistically significant trend of RT over probability within the discrete task. Thus no statistical support for Hypothesis 3 was found. The trend of decreasing RT with increasing probability of occurrence of the S-R pair is apparent (see Figure 3).

Inspection of Figure 3, plus interpretation and speculation on the results obtained, suggest there is a trend of increasing RT with decreasing probability of the S-R pair, consistent with the literature (Smith, 1968a), however there appears to be no difference in the response strategies of the subjects in either the discrete or serial task, with respect to probability of the S-R pair.

FIGURE 5

HYPOTHESIZED ITI BY P INTERACTION



The trend of increasing RT with decreasing probability suggests either (1) that Schutz's assumption of the previous response engram remaining in SA for a short time after the response is elicited is invalid (or SA does not even play a part in response retrievel) or (2) that the response engram fades or is dumped in the period before the onset of the next stimulus. As noted above, this researcher is reluctant to accept the first, due to the fact that (1) the short ITI might not have been short enough, as explained above (the fact that there was no difference between ITI and ITI suggests this), and (2) the high invalid or error rate makes any results speculative. Since the main effect of ITI was non-significant, and assuming the explanation offered in (1) above is plausible, the trend of decreasing RT with increasing probability is expected. This trend of decreasing RT with increasing probability is basic to the "state of preparation" models of Falmagne (1965), Falmagne and Theois (1968), and Schutz (1972), and although not supported empirically, speculation that the serial task is in fact discrete does lend support to these models.

Inter-trial Interval

The analysis indicates there is no difference in RT between the discrete and serial self-paced tasks. The same trends exhibited in both tasks could be explained by the fact that the ITI of 380 msec. (limited by the capacity of the printer at 3 lines/sec) was too long, resulting in both tasks being discrete. Studies reporting the same effects as was hypothesized in this investigation in respect to serial tasks have been found in cases where the ITI was 250 msec. or less (Bertelson and Renkin, 1966; Hale, 1967). Since no precise time has been given for the "state of preparation" to occur, or the amount of time taken for the response engram to fade from SA, this author is reluctant to refute Schutz's model on the basis of the experimental evidence. Rather, it is assumed that the ITIs used did indeed both result in a discrete task.

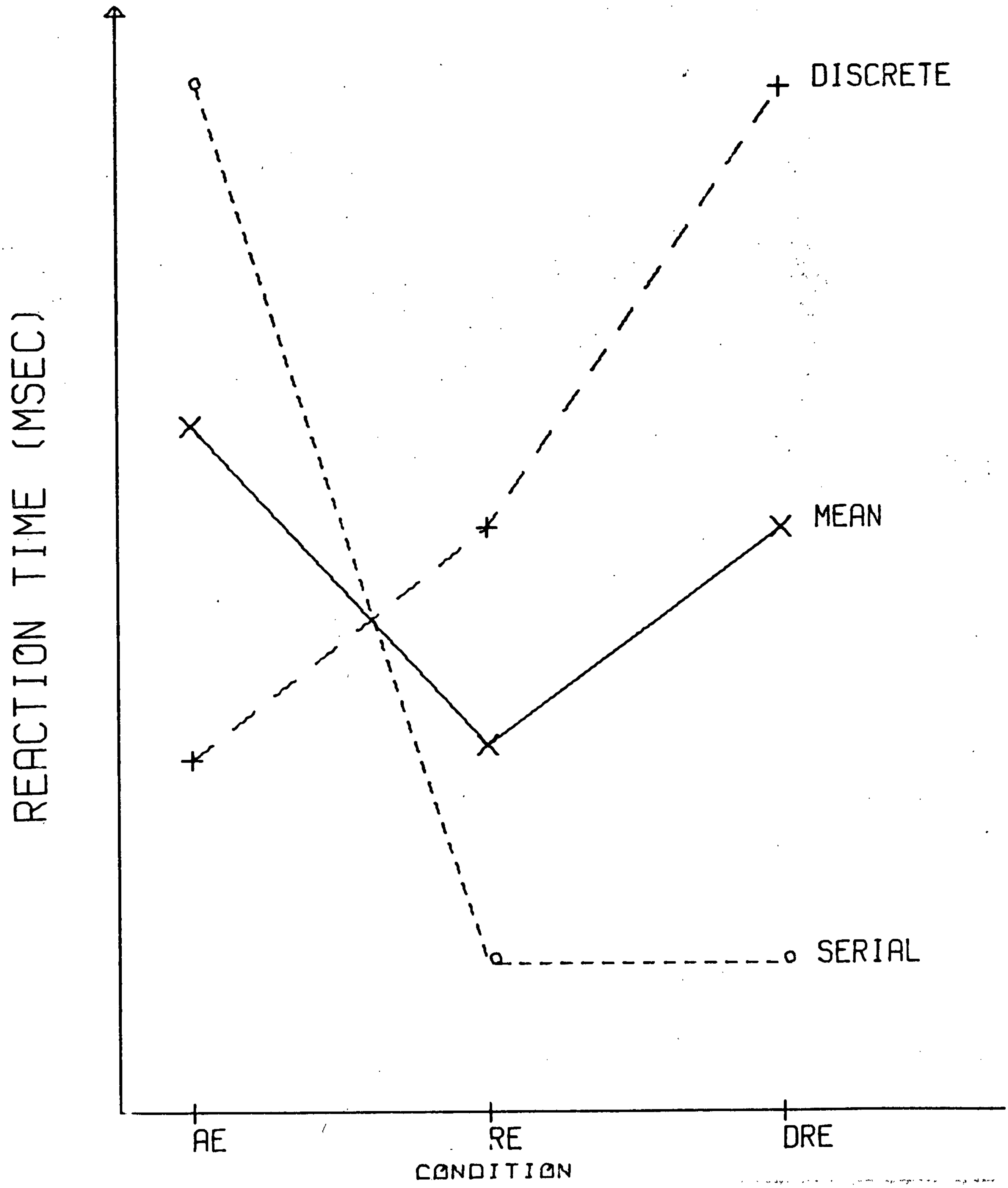
Speculation that the empirical results in regards to inter-trial interval were valid leads to refutation of those models which postulate a "state of preparation" since in a serial task there is no time for such preparation. Other major theories, such as template matching (TM) models and statistical decision models (SDM), don't account for an effect of ITI and thus dubious support of these models is offered. (see Smith, 1968a for an account of TM and SDM models.)

Repetition Effect

The main effect of Condition (R) was significant while the interaction of ITI x R was non-significant. Inspection of Figure 4 reveals the trend of a repetition effect for both the serial and discrete tasks. This was not as predicted as Hypothesis 1 predicts a RE for serial tasks, but an AE for discrete tasks (see Figure 6 below). Since in the main effect analysis means for serial and discrete tasks are combined, the predicted RE for serial tasks would be balanced by the predicted negative RE for the discrete task. In view of the reported literature (Ryan, 1971) on negative REs for discrete tasks, and the obvious trends indicated in Figure 4, further speculative evidence of the subjects response strategies being the same in both tasks is offered. However, presupposing the serial task is actually a discrete task, this trend is opposite to that predicted by Schutz's model, and is in contrast to the reported literature. This could be partially explained by the sequence of trials not being completely random, whereby there where more repetitions than there should have been based on probability, and that the subject therefore prepared for a repetition. This explanation is speculative but if true, would then fit in with the "state of preparation" models. None of the other models reviewed of CRT accounted for a RE in the discrete task.

FIGURE 6

HYPOTHESIZED ITI BY COND INTERACTION



Alternative Explanations of the Data

Neither of the two predicted interacting effects of ITI x P or ITI x R were supported. This would logically lead one to accept the three null hypothesis, until shown otherwise, that there are no differences among any of the experimental conditions. However, this researcher is reluctant to accept the experimental findings on a number of counts. Firstly, the high invalid or error rate casts doubts on any findings. Secondly, the fact that the ITI in the serial self-paced task was approximately 380 msec. might enable the subject to treat the task as a discrete task. Thirdly, the difference between the high and low probabilities might not have been of a great enough difference. Fourthly, and perhaps most importantly, in a 2-choice RT task, the subjects response strategy might be simplified. For instance, a binary search operation might take place, where the response engram is checked, a match would elicit one response program, whereby a no match would elicit the alternate response program. If such was the case there would be too small a difference in search and retrieval time to detect a difference between matched and not matched response program search and release times.

Theoretical Revisions of Schutz's Model

Under the tenuous assumption that the empirical results of this investigation are valid, Schutz's model is refuted. Since the basic premiss of this model is a "state of preparation," whereby the expected RP is place in SA, and the results indicate that stimulus are not selectively prepared for, the model is incompatible with the results. Indeed a two-state stochastic model seems most inappropriate if there is only a one-state memory (long term memory storage being neglected).

Alternative Models

The results of this investigation do not refute the SDM model or the TM model. However, before support is offered for these models, research must be carried out specifically to test these models. Thus, this investigation still leaves many questions unanswered in regard to the repetition effect in short term memory retrieval.

CHAPTER V

SUMMMARY AND CONCLUSIONS

Summary

The main purpose of this study was to investigate the repetition effect in a 2-choice reaction time task in terms of Schutz's theory of information storage and retrieval of a simple motor task. Other problems investigated in the study were (1) the effects of inter-trial interval on the repetition effect, (2) the effect of probability occurrence of a S-R pair on the repetition effect, and (3) the interacting effects of inter-trial interval and probability of occurrence on the repetition effect.

Sixteen (10 female, 6 male) right-handed students and staff of the University of British Columbia were used as subjects. All subjects were tested in all experimental conditions.

The experimental task involved responding as quickly as possible by depressing a key in response to a stimulus light. Two inter-trial intervals and three probabilities of occurrence of the S-R pair were used resulting in six experimental conditions.

The results were separated into alternations, repetitions, and double repetitions. Each was then analyzed along with the effects of probability and inter-trial interval. The results of the analysis indicated no significant differences in any

Conclusions

Due to the large proportion of invalid or error responses (26.3%) any conclusions formulated are tenuous at best. However, the investigation suggests the following conclusions:

1. That there is no repetition effect (RE) or alternation effect (AE) in either a discrete or serial two-choice RT task.

2. That there is no difference in the subjects' response strategies in either a discrete or serial task.

3. That RT is inversely related to probability of occurrence in a two-choice RT task.

4. That Schutz's model of motor memory retrieval is not supported, in that specific relationships between ITI and probability were not found in this investigation.

Suggestions for Further Research

Although basic deductions which followed from the assumptions of Schutz's model of motor memory retrieval were not supported, it is suggested that this experiment be repeated with more reliable equipment before any of Schutz's assumptions are rejected. Also, the investigation should be enlarged to account for CRT tasks of more than 2 choices. The variables of probability, and ITI should also be manipulated over a greater range.

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APPENDIX A

Instructions to Subjects

INSTRUCTIONS TO SUBJECTS

After the subject had been shown how to use the apparatus, and had completed his practice trials for that day, the following instructions were read.

> In today's session the left light will come on (as often as the right, twice as often as the right, one-half as many times as the right) [1]. Please respond to the light as quickly as you can by depressing the appropriate key, however try not to make any errors. The equipment will detect any errors, so if you make one, just proceed as normal. Today the trials will occur (right after each other, with a delay of approximately 2 seconds between each one) [2]. Do you have any questions?

At this point if the subject had any questions they were answered if they were thought not to influence the outcome. The subject was then requested to put on the earphones and proceed.

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[1] only one of the three was read, depending on the condition.

[1] only one was read depending if the subject was in the discrete condition, or the serial condition during that session.

APPENDIX B

Tables

TABLE I APPENDIX B

Expected and Actual Number of Valid S-R Pairs

Within Each Block of 480 Trials

	Prob	AL	RE	DRE	MORE	TOTAL
expected	.33	107	36	11	5	159
actual ITI	.33	94.9	37.1	10.2	6.8	146.9
actual ITI	.33	90.7	28.6	11.5	4.8	144.8
percent of expected		86.7%	91.2%	98.6%	116.0%	91.7%
expected	.50	120	60	30	30	240
actual ITI	.50	92.9	53.1	24.7	14.7	185.4
actual ITI	.50	84.2	49.5	23.3	13.1	170.0
percent of expected		72.8%	85.5%	80.0%	46.3%	74.0%
expected	.67	107	70	47	95	319
actual ITI	.67	87.5	49.6	29.4	40.1	206.6
actual ITI	.67	92.2	51.3	30.1	37.9	211.5
percent of expected		83.9%	72.0%	63.3%	41.1%	65.5%

Table II

Order of Conditions for Each Subject

subject	day 1	2	3	5
1	a	b	d	c
2	b	d	a	c
3	c	a	d	b
4	d	c	b	a
5	a	b	c	d
6	b	d	a	c
7	c	a	d	b
8	d	c	b	a
9	a	b	c	d
10	b	d	a	c
11	c	a	d	c
12	a	b	d	c
13	b	d	a	c
14	c	a	d	b
15	d	c	b	a
16	c	d	b	a

TABLE IIIa

Descriptive Statistics for Each Subject - Day 1

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 01 #CASES 402 CONDITION A-1						
NC	100	97	69	70	29	37
MEAN	368.37	343.08	325.13	315.44	322.99	340.0
MEDIAN	368	348	318	313.5	301	329
SD	65.07	60.84	81.31	48.12	86.39	74.98
SUBJECT 02 #CASES 393 CONDITION B-1						
NC	104	104	62	62	29	32
MEAN	352.02	327.45	313.58	321.68	315.14	321.28
MEDIAN	361	318	308.5	309	308	308
SD	65.07	55.49	54.66	79.14	73.39	100.86
SUBJECT 03 #CASES 396 CONDITION C-4						
NC	119	119	28	71	11	48
MEAN	413.66	390.46	420.96	400.35	398.73	390.56
MEDIAN	411	369	401	387	377	357
SD	61.90	86.05	92.97	101.28	69.35	109.08
SUBJECT 04 #CASES 404 CONDITION D-4						
NC	130	129	32	64	15	34
MEAN	438.71	432.66	452.72	449.53	421.60	429.32
MEDIAN	422	411.0	449	432	398	407
SD	66.32	94.96	51.85	87.06	62.87	81.69
SUBJECT 05 #CASES 415 CONDITION A-1						
NC	104	103	68	73	27	40
MEAN	391.18	399.59	397.26	420.39	398.7	431.75
MEDIAN	387	397	393	410	378	420.5
SD	34.79	54.70	48.09	57.61	54.96	47.02
SUBJECT 06 #CASES 315 CONDITION B-1						
NC	87	82	48	47	26	25
MEAN	330.51	294.67	310.83	354.45	335.96	332.28
MEDIAN	327	288	315	334	320.5	325
SD	70.58	42.11	38.60	78.30	84.18	37.49
SUBJECT 07 #CASES 334 CONDITION C-3						
NC	87	89	52	52	38	16
MEAN	459.01	427.33	410.38	426.60	391.68	407.56
MEDIAN	433	418	394	419	379.0	394
SD	90.48	85.83	81.30	83.23	72.42	63.84
SUBJECT 08 #CASES 346 CONDITION D-4						
NC	110	108	27	57	8	36
MEAN	355.03	296.42	314.48	318.70	340.5	309.11
MEDIAN	358.5	283	315	310	352.5	297.5
SD	60.95	69.15	41.37	89.19	52.28	68.42

TABLE IIIa cont.

Descriptive Statistics for Each Subject - Day 1

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 09 #CASES 245 CONDITION A-2						
NC	63	65	33	43	17	24
MEAN	420.75	379.11	385.58	372.98	398.29	391.33
MEDIAN	407	379.0	366	369	388	383.5
SD	46.69	44.95	69.69	43.20	56.86	58.87
SUBJECT 10 #CASES 415 CONDITION B-2						
NC	113	109	50	78	26	39
MEAN	417.64	410.75	380.36	410.15	380.88	389.0
MEDIAN	400	388	370	386	328.5	382
SD	91.47	101.02	64.32	100.38	130.57	62.84
SUBJECT 11 #CASES 398 CONDITION C-3						
NC	108	109	73	52	44	12
MEAN	376.86	381.44	346.99	388.23	338.41	349.08
MEDIAN	359	367	346	364.0	326.5	359.0
SD	87.15	82.07	79.36	101.51	92.07	50.34
SUBJECT 12 #CASES 404 CONDITION A-1						
NC	101	102	63	75	25	38
MEAN	402.05	350.32	358.13	364.63	358.68	340.03
MEDIAN	398	345	355	354	354	325.5
SD	62.45	65.90	44.17	57.39	59.96	83.85
SUBJECT 13 #CASES 404 CONDITION B-1						
NC	98	97	65	63	31	35
MEAN	445.89	420.28	421.37	428.66	403.54	382.63
MEDIAN	436.5	395	429	415	392	387
SD	90.19	92.48	74.89	84.41	76.29	71.33
SUBJECT 14 #CASES 379 CONDITION C-4						
NC	109	112	26	73	12	47
MEAN	404.39	356.84	433.65	407.48	414.17	392.09
MEDIAN	395	363	415.5	406	396.5	394
SD	52.70	52.31	72.59	56.55	84.12	41.74
SUBJECT 15 #CASES 399 CONDITION D-4						
NC	133	133	34	60	10	31
MEAN	377.93	326.53	361.56	362.57	351.60	352.03
MEDIA	360	308	346	341.5	357	332
SD	72.73	64.60	70.65	70.34	77.36	51.46
SUBJECT 16 #CASES 382 CONDITION C-3						
NC	99	102	67	60	41	13
MEAN	408.15	412.67	375.82	377.65	362.39	401.0
MEDIAN	407	405.5	367	370	363	399
SD	64.36	64.77	60.48	61.97	51.96	76.93

TABLE IIIb

Descriptive Statistics for Each Subject - Day 2

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 01 #CASES 254 CONDITION B-4						
NC	75	75	30	42	11	21
MEAN	347.21	303.85	303.53	317.5	312	314.76
MEDIAN	359	300	292.5	308.5	316	317.00
SD	84.37	41.47	47.64	77.40	53.74	47.38
SUBJECT 02 #CASES 301 CONDITION D-4						
NC	102	101	26	42	5	25
MEAN	356.42	348.64	348.42	358.05	344.40	346.2
MEDIAN	344	339	325.5	334.5	348	334
SD	72.19	65.52	75.49	91.52	45.10	104.55
SUBJECT 03 #CASES 324 CONDITION A-1						
NC	85	81	56	53	27	22
MEAN	395.68	377.30	354.86	322.21	348.07	362.09
MEDIAN	383	363	338.5	317	331.0	354
SD	76.49	89.02	60.65	54.11	75.71	76.64
SUBJECT 04 #CASES 393 CONDITION C-3						
NC	106	108	74	50	51	4
MEAN	405.16	424.40	400.43	438.22	402.63	445.25
MEDIAN	393	416.5	403	420	370	439
SD	64.59	83.88	60.83	94.92	99.21	66.86
SUBJECT 05 #CASES 280 CONDITION B-1						
NC	79	73	45	47	20	21
MEAN	408.77	425.12	400.49	450.17	396.5	409.29
MEDIAN	395	404	376	427	379.5	382
SD	53.99	80.48	89.35	112.46	112.30	76.91
SUBJECT 06 #CASES 332 CONDITION D-3						
NC	96	90	52	49	31	14
MEAN	314.73	324.31	292.21	341.88	280.06	341.43
MEDIAN	302	311	287	345	275	342.5
SD	86.62	80.21	46.19	34.48	35.16	27.26
SUBJECT 07 #CASES 383 CONDITION A-1						
NC	93	96	60	68	28	38
MEAN	391.00	388.21	354.70	360.94	365.04	352.18
MEDIAN	386	376.5	353	357	353.5	346.5
SD	55.36	69.90	30.06	64.70	49.87	38.91
SUBJECT 08 #CASES 272 CONDITION C-4						
NC	83	89	20	47	6	27
MEAN	402.00	346.57	424.95	358.13	385.5	326.67
MEDIAN	404	331	419	335	390	319
SD	68.59	88.02	67.28	110.35	64.85	55.09

TABLE IIIb cont.

Descriptive Statistics for Each Subject - Day 2

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 09 #CASES 356 CONDITION B-2						
NC	92	96	50	63	24	31
MEAN	427.22	369.92	378.24	416.92	391.42	391.55
MEDIAN	429	366	380	416	379	384
SD	51.24	42.31	47.86	42.47	41.51	38.20
SUBJECT 10 #CASES 361 CONDITION B-2						
NC	96	97	66	53	38	11
MEAN	371.52	361.23	359.39	368.91	344.58	335.0
MEDIAN	359.5	355	352	354	342	326.0
SD	78.27	54.23	81.20	61.30	56.39	33.37
SUBJECT 11 #CASES 384 CONDITION A-1						
NC	99	103	61	62	25	34
MEAN	338.56	353.70	296.25	279.76	283.2	296.53
MEDIAN	339	328	286	269	294	276.5
SD	87.15	105.27	58.55	84.39	30.37	117.46
SUBJECT 12 #CASES 333 CONDITION B-1						
NC	91	90	51.65	52	23	26
MEAN	314.33	298.33	301	320.23	281.17	307.85
MEDIAN	307	292.5	313	316	286.0	310.5
SD	67.59	72.37	46.34	39.72	37.11	42.67
SUBJECT 13 #CASES 385 CONDITION D-4						
NC	110	144	29	73	14	45
MEAN	440.74	382.82	394.34	404.96	381.70	399.07
MEDIAN	428.5	368.5	391	396	379	377
SD	70.61	62.89	41.93	63.84	47.94	97.84
SUBJECT 14 #CASES 367 CONDITION A-2						
NC	101	99	66	55	38	8
MEAN	343.36	323.54	319.30	340.87	314.60	318.62
MEDIAN	341	316	305.5	326	307	295.5
SD	50.89	54.29	54.30	62.25	40.81	75.94
SUBJECT 15 #CASES 317 CONDITION C-3						
NC	101	99	24	52	12	29
MEAN	471.77	442.25	426.13	439.62	418.50	446.34
MEDIAN	461	432	419	434	428.50	445
SD	64.06	76.21	38.13	68.90	51.39	73.53
SUBJECT 16 #CASES 414 CONDITION D-4						
NC	120	118	56	66	25	29
MEAN	371.06	347.40	360.36	365.70	359.52	342.76
MEDIAN	367	342.5	352.5	363	345	341
SD	52.25	39.47	45.28	70.36	58.92	35.06

TABLE IIIc

Descriptive Statistics for Each Subject - Day 3

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 01 #CASES 268 DONCITION D-3						
NC	74	65	48	38	37	6
MEAN	301.09	300.75	252.04	315.42	248.59	312.0
MEDIAN	298.5	305	244.5	312.5	250	322.5
SD	50.94	41.32	27.88	35.61	27.98	38.89
SUBJECT 02 #CASES 227 CONDITION A-1						
NC	68	64	33	28	17	14
MEAN	343.43	329.02	338.03	324.39	330.12	327.0
MEDIAN	334.5	308.0	328.0	318	318	334.0
SD	74.62	70.37	49.32	58.18	67.16	57.60
SUBJECT 03 #CASES 222 CONDITION D-4						
NC	65	66	20	37	9	25
MEAN	416.80	386.71	403.75	368.76	414.0	360.64
MEDIAN	399	369.5	406	357	372	352.0
SD	72.57	76.69	44.92	62.20	24.61	62.41
SUBJECT 04 #CASES 357 CONDITION B-2						
NC	96	98	42	66	18	37
MEAN	408.17	422.06	403.95	427.14	399.17	397.76
MEDIAN	398	401	402.0	400	389	377
SD	53.89	94.21	41.76	96.49	47.49	69.26
SUBJECT 05 #CASES 357 CONDITION C-3						
NC	93	91	61	56	40	16
MEAN	344.50	358.65	324.64	339.91	328.65	332.31
MEDIAN	340	353.0	324	337	326	341
SD	49.22	54.66	50.61	33.94	29.23	28.45
SUBJECT 06 #CASES 317 CONDITION A-1						
NC	81	80	50	49	24	27
MEAN	332.96	324.11	313.70	329.16	322	379.81
MEDIAN	315	320.0	299.5	331.0	296	341
SD	71.25	59.79	56.67	51.20	71.31	119.12
SUBJECT 07 #CASES 324 CONDITION D-3						
NC	89	97	49	46	29	14
MEAN	430.63	418.29	377.71	401.54	376.86	372.79
MEDIAN	405	397.0	376.0	401.5	368.0	373.5
SD	104.96	101.31	68.86	56.22	62.25	70.57
SUBJECT 08 #CASES 182 CONDITION B-2						
NC	50	52	21	36	7	16
MEAN	370.7	334.02	351.05	341.67	341.57	314.94
MEDIAN	373	321	345	326	335	312
SD	50.35	81.57	50.07	83.94	60.12	49.24
SUBJECT 09 #CASES 289 CONDITION C-4						

TABLE IIIc cont.

Descriptive Statistics for Each Subject - Day 3

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
NC	91	92	24	45	10	27
MEAN	399.29	349.40	348.58	355.27	328.5	352.15
MEDIAN	395	336	342	342.0	326.5	354.0
SD	35.21	80.09	45.52	47.83	17.80	34.36
SUBJECT 10 #CASES 346 CONDITION A-2						
NC	95	96	55	51	25	24
MEAN	369.81	345.06	353.18	338.02	324.56	317.58
MEDIAN	359	336.5	345.0	334	314	324.5
SD	66.38	42.68	62.00	59.09	36.79	35.70
SUBJECT 11 #CASES 347 CONDITION D-3						
NC	94	93	64	46	39	11
MEAN	296.73	334.12	285.42	336.28	264.90	348.27
MEDIAN	282.5	329	274.5	330	265.0	348
SD	61.77	72.7	54.27	46.34	39.30	51.98
SUBJECT 12 #CASES 200 CONDITION D-4						
NC	68	71	14	29	6	12
MEAN	295.10	284.94	298.36	326.90	284.67	292.08
MEDIAN	275.5	265	304.5	307	295	299.5
SD	87.50	98.19	60.63	87.43	35.65	46.80
SUBJECT 13 #CASES 380 CONDITION A-1						
NC	100	96	61	66	25	32
MEAN	407.54	401.97	370.25	363.85	360.80	360.06
MEDIAN	408.5	387.5	357	349.0	340	348.5
SD	48.08	82.09	76.09	78.72	71.86	69.75
SUBJECT 14 #CASES 293 CONDITION D-4						
NC	87	90	23	53	11	29
MEAN	359.67	343.32	384.69	341.98	336.36	326.45
MEDIAN	329	335	361.0	337	334	321
SD	38.56	72.10	91.33	36.78	31.30	49.31
SUBJECT 15 #CASES 372 CONDITION B-2						
NC	103	101	52	65	19	32
MEAN	404.13	354.65	383.31	355.95	362.63	366.97
MEDIAN	378	338	357.0	338	361	346
SD	82.21	60.51	91.66	60.15	44.21	57.84
SUBJECT 16 #CASES 388 CONDITION B-1						
NC	102	104	63	61	30	28
MEAN	448.13	420.84	357.83	409.56	375.27	416.93
MEDIAN	445.5	410	369.0	359.0	363	410.5
SD	76.15	80.01	56.08	74.32	74.24	67.36

TABLE IIId

Descriptive Statistics for Each Subject - Day 4

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 01 #CASES 383 CONDITION C-3						
NC	108	107	73	44	43	8
MEAN	305.37	321.60	255.42	288.54	269.37	316.0
MEDIAN	313.5	317	254	295.5	253	309
SD	77.42	101.80	39.50	61.26	76.59	34.22
SUBJECT 02 #CASES 328 CONDITION C-4						
NC	109	105	27	48	314	25
MEAN	331.17	305.53	376.52	353.13	326.86	323.04
MEDIAN	323.0	284	355	320	327	308
SD	84.05	87.32	83.08	98.56	36.29	110.27
SUBJECT 03 #CASES CONDITION B-1						
NC	88	91	53	55	17	25
MEAN	368.91	365.25	358.15	359.07	357.24	340.20
MEDIAN	360	362	348	345	346	346.0
SD	46.77	62.81	61.66	72.12	41.99	28.44
SUBJECT 04 #CASES 347 CONDITION A-2						
NC	104	99	44	55	22	23
MEAN	397.97	373.67	343.5	366.18	313.64	373.91
MEDIAN	384.5	365	343	362	315.5	379
SD	73.07	75.71	45.45	67.46	43.29	59.13
SUBJECT 05 #CASES 65 CONDITION D-3						
NC	22	19	12	6	5	1
MEAN	399.41	470.89	383.58	374.83	391.80	374
MEDIAN	384	423.0	367	363.5	394	374
SD	74.22	129.56	54.25	32.32	42.56	0
SUBJECT 06 #CASES 29 CONDITION C-3						
NC	19	9	5	2	2	1
MEAN	349	372.0	335.2	360	346.0	253
MEDIAN	363	384	320	360	346.0	253
SD	50.59	64.38	40.51	76.37	11.31	0
SUBJECT 07 #CASES 0 CONDITION B-1						
SUBJECT 08 #CASES 234 CONDITION A-2						
NC	68	66	29	40	15	16
MEAN	400.10	318.39	365.41	288.02	316.67	273.63
MEDIAN	406	285.5	361	290	305	271.5
SD	80.21	92.51	79.11	43.99	45.51	39.95

TABLE IIId cont.

Descriptive Statistics for Each Subject - Day 4

Condition	AE A	AE B	RE A	RE B	DRE A	DRE B
SUBJECT 09 #CASES 0 CONDITION D-4						
SUBJECT 10 #CASES 218 CONDITION C-3						
NC	66	63	35	28	20	6
MEAN	327.21	320.40	311.49	315.14	320.55	207.5
MEDIAN	322	320	320.0	306.0	324.5	311.5
SD	69.17	71.48	35.77	61.50	56.85	32.12
SUBJECT 11 #CASES 321 CONDITION B-1						
NC	83	86	51	50	25	26
MEAN	273.35	286.43	287.96	304.46	278.40	273.31
MEDIAN	262	278.0	273.0	298.5	275	275.5
SD	50.28	52.38	74.45	46.81	27.85	24.50
SUBJECT 12 #CASES 235 CONDITION C-4						
NC	75	74	21	38	7	20
MEAN	321.44	277.91	328.19	309.53	324.71	266.80
MEDIAN	331	257.5	329.0	305	289	259
SD	73.99	77.83	48.22	61.85	81.23	31.87
SUBJECT 13 #CASES 80 CONDITION C-4						
NC	28	21	12	10	3	5
MEAN	447.29	434.59	392.08	366.90	425.0	408.80
MEDIAN	441	436	360.5	355.5	466	377
SD	74.67	89.65	85.78	30.18	82.53	102.50
SUBJECT 14 #CASES 81 CONDITION B-2						
NC	24	19	15	14	5	4
MEAN	329.25	318.58	356.67	302.64	305.0	307.75
MEDIAN	323.5	319	346.0	297.0	291.0	305
SD	58.36	54.99	61.05	24.71	37.20	142.25
SUBJECT 15 #CASES 353 CONDITION A-2						
NC	88	87	42	59	23	34
MEAN	362.86	308.44	324.79	352.42	319.35	357.82
MEDIAN	351	300.0	305.5	316.0	306	338
SD	71.62	47.12	63.53	42.39	46.17	93.40
SUBJECT 16 #CASES 116 CONDITION A-1						
NC	37	30	15	17	11	6
MEAN	409.89	358.47	409.93	397.06	430.64	359.0
MEDIAN	395	358.5	416.0	378	400	351.5
SD	56.05	62.02	67.36	78.28	118.24	25.46

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TRIAL NO. 1

		AA	BB	A1	B1	A2	B2	AM	BM
SUBJ.#	1	103	99	70	72	30	37	13	19
SUBJ.#	2	104	104	64	66	30	33	16	23
SUBJ.#	3	122	119	28	71	12	48	1	67
SUBJ.#	4	130	129	32	64	15	34	2	49
SUBJ.#	5	104	103	68	73	27	40	12	14
SUBJ.#	6	87	82	48	47	26	25	12	12
SUBJ.#	7	87	89	52	52	38	16	44	23
SUBJ.#	8	110	108	27	57	8	36	3	45
SUBJ.#	9	63	65	33	43	17	24	2	36
SUBJ.#	10	113	109	50	78	26	39	4	43
SUBJ.#	11	108	109	73	52	44	12	34	5
SUBJ.#	12	101	102	63	75	25	38	12	23
SUBJ.#	13	98	97	65	63	31	35	16	23
SUBJ.#	14	109	112	26	73	12	47	1	70
SUBJ.#	15	133	131	34	60	10	31	2	57
SUBJ.#	16	99	102	67	60	41	13	34	20

TRIAL NO. 2

		AA	BB	A1	B1	A2	B2	AM	BM
SUBJ.#	1	75	75	30	42	11	21	4	15
SUBJ.#	2	102	101	26	42	5	25	3	47
SUBJ.#	3	85	81	56	53	27	22	12	14
SUBJ.#	4	106	108	74	50	51	4	52	2
SUBJ.#	5	74	73	45	47	20	21	12	13
SUBJ.#	6	96	90	52	49	31	14	21	15
SUBJ.#	7	93	96	60	68	28	38	12	28
SUBJ.#	8	83	89	20	47	6	27	4	38
SUBJ.#	9	92	96	50	63	24	31	7	53
SUBJ.#	10	96	97	66	53	38	11	35	10
SUBJ.#	11	99	103	61	62	25	34	14	21
SUBJ.#	12	91	90	51	52	23	26	11	8
SUBJ.#	13	110	114	29	73	14	45	0	65
SUBJ.#	14	101	99	66	55	38	8	41	10
SUBJ.#	15	120	118	56	66	25	29	5	30
SUBJ.#	16	101	99	24	52	12	29	0	41

TRIAL NO. 3

		AA	BB	A1	B1	A2	B2	AM	BM
SUBJ.#	1	74	65	48	38	37	6	30	6
SUBJ.#	2	68	64	33	31	17	14	7	10
SUBJ.#	3	65	66	20	37	9	25	0	32
SUBJ.#	4	96	98	42	66	18	37	3	30
SUBJ.#	5	93	91	61	56	40	16	40	13
SUBJ.#	6	81	80	50	55	24	27	14	11
SUBJ.#	7	89	97	49	46	29	14	35	6
SUBJ.#	8	50	52	21	36	7	16	1	14
SUBJ.#	9	91	92	24	45	10	27	1	38
SUBJ.#	10	95	96	55	51	25	24	7	28
SUBJ.#	11	94	93	64	46	39	11	42	10
SUBJ.#	12	68	71	14	29	6	12	1	15
SUBJ.#	13	100	96	61	66	25	32	14	10
SUBJ.#	14	87	90	23	53	11	29	4	46
SUBJ.#	15	103	101	52	65	19	32	3	39
SUBJ.#	16	102	104	63	61	30	28	13	11

TRIAL NO. 4

SUBJ.#	1	108	107	73	44	43	8	65	6
SUBJ.#	2	109	105	27	48	14	25	2	32
SUBJ.#	3	88	91	53	55	17	25	9	8
SUBJ.#	4	111	104	48	59	23	24	6	30
SUBJ.#	5	22	19	12	6	5	1	2	2
SUBJ.#	6	10	9	5	2	2	1	1	2
SUBJ.#	7	68	66	29	40	15	16	2	19
SUBJ.#	8	66	63	35	28	20	6	30	6
SUBJ.#	9	83	86	51	50	25	26	9	14
SUBJ.#	10	75	74	21	38	7	20	2	34
SUBJ.#	11	28	22	12	10	3	5	1	3
SUBJ.#	12	20	11	15	8	3	4	1	0
SUBJ.#	13	102	104	46	71	25	37	4	33
SUBJ.#	14	24	14	12	8	10	3	6	0

$COPY *SKIP

REPEAT - THE DEPENDENT VARIABLE BEFORE COLLAPSING OVER P=.5 CONDITION

313.5	254.	253.	368.	318.	301.	348.	313.5	329.	317.	295.5	309.	011
298.5	244.5	250.	359.	292.5	316.	300.	308.5	317.	305.	312.5	322.	012
284.	320.	308.	334.5	328.	318.	308.	334.	323.	355.	355.	327.	021
339.	334.5	334.	362.	308.5	308.	318.	309.	308.	344.	325.5	348.	022
369.	387.	377.	383.	338.5	331.	363.	317.	354.	411.	401.	377.	031
369.5	357.	352.	360.	348.	346.	362.	345.	346.	399.	406.	372.	032
393.	403.	370.	384.5	343.	315.5	365.	362.	379.	416.5	420.	439.	041
411.	432.	407.	398.	402.	389.	401.	400.	377.	429.	449.	398.	042
340.	324.	326.	387.	393.	378.	397.	410.	420.5	353.	337.	341.	051
384.	367.	394.	395.	376.	379.5	404.	427.	382.	423.	363.5	374.	052
363.	320.	346.5	315.	299.5	296.	320.	331.	341.	384.	360.	253.	061
302.	287.	275.	327.	315.	320.5	288.	334.	325.	311.	345.	342.5	062
331.	335.	319.	406.	361.	305.	285.5	290.	271.5	404.	419.	390.	081
283.	310.	297.5	373.	345.	335.	321.	326.	312.	358.5	315.	352.5	082
322.	320.	324.5	359.	345.	314.	336.5	334.	324.5	320.	306.	311.5	101
359.5	352.	342.	400.	370.	328.5	388.	386.	382.	355.	354.	326.	102
359.	347.	326.5	339.	286.	294.	328.	269.	276.5	267.	364.	359.	111
282.5	274.5	265.	262.	273.	275.	278.	298.5	275.5	329.	330.	348.	112
257.5	305.	259.	398.	355.	354.	345.	354.	325.5	331.	329.	289.	121
265.	307.	299.5	307.	313.	286.	292.5	316.	310.5	275.5	304.5	295.	122
436.	355.5	277.	408.5	357.	340.	387.5	249.	348.5	441.	360.5	466.	131
368.5	396.	377.	436.5	429.	392.	395.	415.	387.	428.5	391.	379.	132
363.	406.	394.	341.	305.5	307.	316.	326.	295.5	395.	415.5	396.5	141
335.	337.	321.	323.5	346.	291.	319.	297.	305.	329.	361.	334.	142
461.	419.	423.5	351.	305.5	306.	300.	316.	338.	432.	434.	445.	151
308.	341.5	332.	378.	357.	361.	338.	338.	346.	360.	346.	357.	152
407.	367.	363.	395.	416.	400.	358.5	378.	351.5	405.5	370.	399.	161
342.5	363.	341.	445.5	369.	363.	410.	395.	410.5	367.	352.5	345.	162

$COPY *SKIP

```
$COPY P551:DEPEND(*F)
C  DEPEND - THE DEPENDENT VARIABLES FOR THE 14 SUBJECTS IN THE 18 CONDITIONS
   313.5 254.0 253.0 358.0 315.8 315.0 317.0 295.5 309.0         1100
   298.5 244.5 250.0 329.5 300.5 316.5 305.0 312.5 322.0         1200
   284.0 320.0 308.0 321.3 331.0 320.5 355.0 355.0 327.0         2100
   339.0 334.5 334.0 340.0 308.8 308.0 344.0 325.5 348.0         2200
   369.0 387.0 377.0 373.0 327.8 342.5 411.0 401.0 377.0         3100
   369.5 357.0 352.0 361.0 346.5 346.0 399.0 406.0 372.0         3200
   393.0 403.0 370.0 374.8 352.5 347.3 416.5 420.0 439.0         4100
   411.0 432.0 407.0 399.5 401.0 383.0 429.0 449.0 398.0         4200
   340.0 324.0 326.0 392.0 401.5 399.3 353.0 337.0 341.0         5100
   384.0 367.0 394.0 399.5 401.5 380.8 423.0 363.5 374.0         5200
   363.0 320.0 346.5 317.5 315.3 318.5 384.0 360.0 253.0         6100
   302.0 287.0 275.0 307.5 324.5 322.8 311.0 345.0 342.5         6200
   331.0 335.0 319.0 345.8 325.5 288.3 404.0 419.0 390.0         8100
   283.0 310.0 297.5 347.0 335.5 323.5 358.5 315.0 352.5         8200
   322.0 320.0 324.5 347.8 339.5 319.3 320.0 306.0 311.5          100
   359.5 352.0 342.0 394.0 378.0 355.3 355.0 354.0 326.0          200
   359.0 347.0 326.5 333.5 277.5 285.3 267.0 364.0 359.0         1100
   282.5 274.5 265.0 270.0 285.8 275.3 329.0 330.0 348.0         1200
   257.5 305.0 259.0 371.5 354.5 339.8 331.0 329.0 289.0         2100
   265.0 307.0 299.5 299.8 314.5 298.3 275.5 304.5 295.0         2200
   436.0 355.5 277.0 398.0 303.0 344.3 441.0 360.5 466.0         3100
   368.5 396.0 377.0 415.8 422.0 389.5 428.5 391.0 379.0         3200
   363.0 406.0 394.0 328.5 315.8 301.3 395.0 415.5 396.5         4100
   335.0 337.0 321.0 321.3 321.5 298.0 329.0 361.0 334.0         4200
   461.0 419.0 423.5 325.5 310.8 322.0 432.0 434.0 445.0         5100
   308.0 341.5 332.0 358.0 347.5 353.5 360.0 346.0 357.0         5200
   407.0 367.0 363.0 376.8 397.0 375.8 405.5 370.0 399.0         6100
   342.5 363.0 341.0 427.8 382.0 386.8 367.0 352.5 345.0         6200


$COPY *SKIP
```

APPENDIX C

COMPUTER PROGRAMS

```
$COPY P551:READATA
      DIMENSION A(500), IA(500)
C   PROGRAM TO READ DAVE'S THESIS DATA
C   WRITE ON UNIT 6 THE TIMES IN COLUMNS ACCORDING TO EFFECT
C      COL 1  ALTERNATION FORM LEFT TO RIGHT
C      COL 2  ALTERNATION FORM RIGHT TO LEFT
C      COL 3  A SINGLE REPETITION OF THE RIGHT
C      COL 4  A SINGLE REPETITION OF THE LEFT
C      COL 5  A DOUBLE REPETITION OF THE RIGHT
C      COL 6  A DOUBLE REPETITION OF THE LEFT
C      COL 7  MORE THAN A DOUBLE REPETITION OF THE RIGHT
C      COL 8  MORE THAN A DOUBLE REPETITION OF THE LEFT
C   TABULATE NUMBER OF EACH AND WRITE ON UNIT 7
C
     INTEGER AA, BB, A1, B1, A2, B2, AM, BM
     WRITE(7,502)
      DO 520 NT=1,4
      WRITE(7,507) NT
     DO 500 NS=1,16
     AA = 0.0
     BB = 0.0
     A1 = 0.0
     A2 = 0.0
     AM = 0.0
     B1 = 0.0
     B2 = 0.0
     BM = 0.0
C
C   READ IN THE DATA INTO THE ARRAY A
C
      READ(5,801) (A(I), I=2,481)
      A(1) = 999.
      A(481) = 999.
C
C  SET POSITIVE TIMES TO 1, NEGATIVE TIMES TO 0
C  TIMES OF |999| OR 000 TO 9   IN THE ARRAY IA
C
      DO 20 I=1,481
      IF ( ABS(A(I)) .GT. 900) GO TO 101
      IF ( ABS(A(I)) .LT. 50) GO TO 101
      IF ( A(I) .GT. 0.0 ) GO TO 102
      IA(I) = 0
      GO TO 20
102   IA(I) = 1
      GO TO 20
101   IA(I) = 9
 20   CONTINUE
C
C  CHANGE VALUE OF IA(I) TO ACCOUNT FOR TIMER LAG
C  IA(I) EQUALS IA(I+1) UNLESS IA(I)=9, WHEREBY IT
C  REMAINS AS 9
C  NOTE THAT IF IA(I) WAS A VALID SCORE IT IS NOW
C  CHANGED TO AN INVALID SCORE OF 9 IF IA(I+1) WAS
C  INVALID
C  THIS IS OKAY SINCE THE SCORE JUST BEFORE AN INVALID
C  SCORE IS ALSO INVALID SINCE YOU CAN'T TELL WHAT IS WAS
```

```
C
C  FOR TRIAL ONE SKIP THE NEXT PART FOR SUBJECTS 1,2,&3
C  SINCE THEIR TIMES HAVE BEEN ALTERED TO TAKE INTO
C  ACCOUNT THE TIMER LAG
C
      IF (NT .EQ.1 .AND. NS .LE. 3) GO TO 318
      DO 30 I=2,481
      IF (IA(I) .EQ. 9) GO TO 30
      IA(I) =  IA(I+1)
 30   CONTINUE
C
C  AFTER A 9 IS FOUND CHECK FOR EFFECTS
C  NOW START CHECKING FOR EFFECTS
C
318   I = 2
302   CONTINUE
      IF (IA(I) .EQ. 9 .OR. IA(I-1) .EQ. 9 ) GO TO 301
C
C  FIND FIRST ALTERNATION AFTER A 9
C
309   CONTINUE
      IF (IA(I) .EQ. IA(I-1) ) GO TO 301
C
C  AN ALTERNATION
C
305   CONTINUE
      IF (IA(I) .EQ. 1) GO TO 303
      WRITE(6,901) A(I)
      AA = AA+1
      GO TO 304
303   WRITE(6,902) A(I)
      BB = BB +1
304   CONTINUE
C
C  LOOK FOR NEXT EFFECT
C
308   I = I + 1
       IF (I .GE. 481) GO TO 505
      IF (IA(I) .EQ. 9 .OR. IA(I-1) .EQ. 9 ) GO TO 301
C
C  TEST FOR ANOTHER ALTERNATION
      IF (IA(I) .NE. IA(I-1) ) GO TO 305
C
C  A REPETITION OF SOME SORT
C
      IF (IA(I) .EQ. IA(I-2)) GO TO 306
C
C  A SINGLE REPETITION
C
      IF (IA(I) .EQ. 1) GO TO 307
      WRITE(6,903) A(I)
     A1 = A1 + 1
      GO TO 308
 307  WRITE(6,904) A(I)
     B1 = B1 + 1
      GO TO 308
306   CONTINUE
      IF (IA(I) .EQ. IA(I-3)) GO TO 312
C
C  A DOUBLE REPETITION
```

```
C
       IF (IA(I) .EQ.1) GO TO 310
       WRITE(6,905) A(I)
       A2 = A2 + 1
       GO TO 308
 310   WRITE(6,906) A(I)
       B2 = B2 + 1
       GO TO 308
 312   CONTINUE
C
C  MORE THAN A DOUBLE REPETION
C
       IF (IA(I) .EQ.1) GO TO 311
       WRITE(6,907) A(I)
        AM = AM + 1
       GO TO 308
 311   WRITE(6,908) A(I)
        BM = BM + 1
       GO TO 308
301    CONTINUE
       I = I+1
       IF (I .GE. 481) GO TO 505
       GO TO 302
505   WRITE(7,501) NS, AA, BB, A1, B1, A2, B2, AM, BM
500   CONTINUE
 520   CONTINUE
501   FORMAT(' SUBJ.#',9I5)
502   FORMAT('1',8X,7X,'AA   BB   A1   B1   A2   B2   AM   BM')
 507   FORMAT('1   TRIAL NO.',I4,/,'-')
801   FORMAT(16F4.0)
C
C  THE FORMAT STATEMENTS
C
 901    FORMAT(' ',F5.0)
 902    FORMAT(' ',5X,F5.0)
 903    FORMAT(' ',10X,F5.0)
 904    FORMAT(' ',15X,F5.0)
 905    FORMAT(' ',20X,F5.0)
 906   FORMAT(' ',25X,F5.0)
 907    FORMAT(' ',30X,F5.0)
 908    FORMAT(' ',35X,F5.0)
       END


$COPY *SKIP
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```
$COPY P551:FREQCOUNT
C
C   FREQCOUNT A PROGRAM TO COUNT THE NUMBER OF EACH EFFECTS
C
        DIMENSION A(500), IA(500)
        READ(5,801)  (A(I), I=2,481)
        A(1) = 999.
        A(481) = 999.
C
C   SET POSITIVE TIMES TO 1, NEGATIVE TIMES TO 0
C   TIMES OF |999| OR |000| TO 9 IN THE ARRAY IA
C
        DO 20 I=1,481
        IF ( ABS(A(I)) .GT. 900) GO TO 101
        IF ( ABS(A(I)) .LT. 50) GO TO 101
        IF ( A(I) .GT. 0.0) GO TO 102
        IA(I) = 0
        GO TO 20
 102    IA(I)=1
        GO TO 20
 101    IA(I) = 9
  20    CONTINUE
C
C    AFTER A 9 IS FOUND CHECK FOR EFFECTS
C    NOW START CHECKING FOR EFFECTS
C
        I=2
302     CONTINUE
        IF (IA(I).EQ.9.OR.IA(I-1).EQ.9.OR.IA(I+1).EQ.9)
    1   GO TO 301
C
C    FIND FIRST ALTERNATION AFTER A 9
C
 309    CONTINUE
        IF (IA(I) .EQ. IA(I-1)) GO TO 301
C
C    AN ALTERNATION
C
 305    CONTINUE
        IF (IA(I) .EQ. 1) GO TO 303
        WRITE(6,901) A(I)
        GO TO 304
 303    WRITE(6,902) A(I)
 304    CONTINUE
C
C   LOOK OF THE NEXT EFFECT
C
 308    I = I + 1
        IF (I .GE. 481) STOP
        IF (IA(I).EQ.9.OR.IA(I-1).EQ.9.OR.IA(I+1).EQ.9)
    1   GO TO 301
C
C    TEST FOR ANOTHER ALTERNATION
        IF (IA(I) .NE. IA(I-1)) GO TO 305
C
C    A  REPETITION OF SOME SORT
```

```
C
        IF (IA(I) .EQ. IA(I-2)) GO TO 306
C
C   A SINGLE REPETITION
C
        IF (IA(I) .EQ. 1 ) GO TO 307
        WRITE(6,903) A(I)
        GO TO 308
307     WRITE(6,904) A(I)
        GO TO 308
306     CONTINUE
        IF (IA(I) .EQ. IA(I-3)) GO TO 309
C
C   A DOUBLE REPETITION
C
        IF (IA(I) .EQ. 1 ) GO TO 310
        WRITE(6,905) A(I)
        GO TO 308
310     WRITE(6,906) A(I)
        GO TO 308
312     CONTINUE
C
C   MORE THAN A DOUBLE REPETITION
C
        IF (IA(I) .EQ. 1 ) GO TO 311
        WRITE(6,907) A(I)
        GO TO 308
311     WRITE(6,908) A(I)
        GO TO 308
301     CONTINUE
        I = I + 1
        IF (I .GE. 481) STOP
        GO TO 302
801     FORMAT(16F4.0)
C
C   THE FORMAT STATEMENTS
C
 901    FORMAT(' ',F5.0)
 902    FORMAT(' ',5X,F5.0)
 903    FORMAT(' ',10X,F5.0)
 904    FORMAT(' ',15X,F5.0)
 905    FORMAT(' ',20X,F5.0)
 906    FORMAT(' ',30X,F5.0)
 907    FORMAT(' ',35X,F5.0)
 908    FORMAT(' ',40X,F5.0)
          END
$DATA


$COPY *SKIP
```

```
$COPY P551:MEANMED
C
C   PROGAM TO COLLAPSE THE MEASURES FOR P=.5 FOR RIGHT AND LEFT HAND
C   FOR THESIS DATA
C
      DIMENSION X(12),Y(12)
      DO 10 I=1,28
      READ(5,21)  (X(J), J=1,12), IS
      Y(1)  = X(1)
      Y(2)  = X(2)
      Y(3)  = X(3)
      Y(4)  =  (X(4)  + X(7))/2.0
      Y(5)  =  (X(5)  + X(8))/2.0
      Y(6)  =  (X(6)  + X(9))/2.0
      Y(7)  = X(10)
      Y(8)  = X(11)
      Y(9)  = X(12)
      WRITE(6,22)  (Y(J), J=1,9), IS
   10 CONTINUE
   21 FORMAT(3X,12F6.1,3X,I4)
   22 FORMAT(2X,9F6.1,19X,I4)
      STOP
      END


$COPY *SKIP
```

```
$COPY GRAPH1(*F)
C     PROGRAM TO PLOT GRAPH 1 FOR THESIS DATA
C
      REAL SY(3), DY(3), MY(3), X(3),Y(3), DUM(3)
      READ(5,101) (SY(I), I=1,3)
      READ(5,101) (DY(I), I=1,3)
      READ(5,101) (MY(I), I=1,3)
      WRITE(6,102) (SY(I), I=1,3)
      READ(5,101) (DUM(I), I=1,3)
      WRITE(6,102) (DY(I), I=1,3)
      WRITE(6,102) (MY(I), I=1,3)
      X1 = .5
      X2 = 2.5
      X3 = 4.5
      X(1)=0.0
      X(2)=6.0
      Y(1)=0.0
      Y(2)=0.0
      CALL SCALE(DUM,3,8.0,XMIN,DX,1)
      WRITE(6,103) XMIN,DX
103   FORMAT('0',2F8.3)
      DO 10 I=1,3
      SY(I) = (SY(I) - XMIN)/DX
      DY(I) = (DY(I) - XMIN)/DX
      MY(I) = (MY(I) - XMIN)/DX
 10   CONTINUE
      WRITE(6,102) (SY(I), I=1,3)
      WRITE(6,102) (DY(I), I=1,3)
      WRITE(6,102) (MY(I), I=1,3)
      CALL SYMBOL(2.0,9.0,.28,'FIGURE 3',0.0,8)
      CALL SYMBOL(1.5,8.25,.14,'ITI BY PROBABILITY',0.0,18)
      CALL AXIS(0.0,0.0,'REACTION TIME (MSEC)',20,7.5,90.0,XMIN,DX)
      CALL LINE(X,Y,2,1)
      CALL SYMBOL(X1,0.0,0.07,13,0.0,-1)
      CALL SYMBOL(X2,0.0,0.07,13,0.0,-1)
      CALL SYMBOL(X3,0.0,0.07,13,0.0,-1)
      CALL SYMBOL(X1,-.21,.14,'P',0.0,1)
      CALL SYMBOL(X2,-.21,.14,'P',0.0,1)
      CALL SYMBOL(X3,-.21,.14,'P',0.0,1)
      CALL SYMBOL(.6,-.25,.07,'.67',0.0,3)
      CALL SYMBOL(2.6,-.25,.07,'.50',0.0,3)
      CALL SYMBOL(4.6,-.25,.07,'.33',0.0,3)
      CALL SYMBOL(2.0,-.5,.21,'PROBABILITY',0.0,11)
      CALL SYMBOL(X1,SY(1),.14,30,0.0,-1)
      CALL DASHLN(0.07,0.07,0.07,0.07)
      CALL PLOT(X2,SY(2),4)
      CALL SYMBOL(X2,SY(2),.14,30,0.0,-1)
      CALL PLOT(X3,SY(3),4)
      CALL SYMBOL(X3,SY(3),.14,30,0.0,-1)
      XX= X3 + .25
      CALL SYMBOL(XX,SY(3),.14,'SERIAL',0.0,6)
      CALL SYMBOL(X1,DY(1),.14,3,0.0,-1)
      CALL DASHLN(0.14,0.14,0.14,0.14)
      CALL PLOT(X2,DY(2),4)
      CALL SYMBOL(X2,DY(2),.14,3,0.0,-1)
      CALL PLOT(X3,DY(3),4)
```

```
              CALL SYMBOL(X3,DY(3),.14,3,0.0,-1)
              XX= X3 + .25
              CALL SYMBOL(XX,DY(3),.14,'DISCRETE',0.0,8)
              CALL SYMBOL(X1,MY(1),.14,4,0.0,-1)
              CALL SYMBOL(X2,MY(2),.14,4,0.0,-2)
              CALL SYMBOL(X3,MY(3),.14,4,0.0,-2)
              XX= X3 + .25
              CALL SYMBOL(XX,MY(3),.14,'MEAN',0.0,4)
              CALL PLOTND
         101  FORMAT(3F6.1)
         102  FORMAT(' ',3F6.1)
              STOP
              END
       $DATA
END OF FILE


$COPY *SKIP
```

```
              CALL SYMBOL(X3,DY(3),.14,3,0.0,-1)
              XX= X3 + .25
              CALL SYMBOL(XX,DY(3),.14,'DISCRETE',0.0,8)
              CALL SYMBOL(X1,MY(1),.14,4,0.0,-1)
              CALL SYMBOL(X2,MY(2),.14,4,0.0,-2)
              CALL SYMBOL(X3,MY(3),.14,4,0.0,-2)
              XX= X3 + .25
              CALL SYMBOL(XX,MY(3),.14,'MEAN',0.0,4)
              CALL PLOTND
        101   FORMAT(3F6.1)
        102   FORMAT(' ',3F6.1)
              STOP
              END
       $DATA
END OF FILE


$COPY *SKIP
```

```
$LIST P551:GRAPH2(*F)
      C     PROGRAM TO PLOT GRAPH 2 FOR THESIS DATA
      C
            REAL SY(3), DY(3), MY(3), X(3),Y(3), DUM(3)
            READ(5,101)  (SY(I), I=1,3)
            READ(5,101)  (DY(I), I=1,3)
            READ(5,101)  (MY(I), I=1,3)
            WRITE(6,102)  (SY(I), I=1,3)
            READ(5,101)  (DUM(I), I=1,3)
            WRITE(6,102)  (DY(I), I=1,3)
            WRITE(6,102)  (MY(I), I=1,3)
            X1 = .5
            X2 = 2.5
            X3 = 4.5
            X(1)=0.0
            X(2)=6.0
            Y(1)=0.0
            Y(2)=0.0
            CALL SCALE(DUM,3,8.0,XMIN,DX,1)
            WRITE(6,103) XMIN,DX
       103  FORMAT('0',2F8.3)
            DO 10 I=1,3
            SY(I) = (SY(I) - XMIN)/DX
            DY(I) = (DY(I) - XMIN)/DX
            MY(I) = (MY(I) - XMIN)/DX
        10  CONTINUE
            WRITE(6,102)  (SY(I), I=1,3)
            WRITE(6,102)  (DY(I), I=1,3)
            WRITE(6,102)  (MY(I), I=1,3)
            CALL SYMBOL(2.0,9.0,.28,'FIGURE 4',0.0,8)
            CALL SYMBOL(1.5,8.25,.14,'REPETITION EFFECT BY ITI',0.0,24
            CALL AXIS(0.0,0.0,'REACTION TIME (MSEC)',20,7.5,90.0,XMIN,
            CALL LINE(X,Y,2,1)
            CALL SYMBOL(X1,0.0,0.14,13,0.0,-1)
            CALL SYMBOL(X2,0.0,0.14,13,0.0,-1)
            CALL SYMBOL(X3,0.0,0.14,13,0.0,-1)
            CALL SYMBOL(X1,-.25,.14,'AE',0.0,2)
            CALL SYMBOL(X2,-.25,.14,'RE',0.0,2)
            CALL SYMBOL(X3,-.25,.14,'DRE',0.0,3)
            CALL SYMBOL(2.0,-0.5,.14,'CONDITION',0.0,9)
            CALL SYMBOL(X1,SY(1),.14,30,0.0,-1)
            CALL DASHLN(0.07,0.07,0.07,0.07)
            CALL PLOT(X2,SY(2),4)
            CALL SYMBOL(X2,SY(2),.14,30,0.0,-1)
            CALL PLOT(X3,SY(3),4)
            CALL SYMBOL(X3,SY(3),.14,30,0.0,-1)
            XX= X3 + .25
            CALL SYMBOL(XX,SY(3),.14,'SERIAL',0.0,6)
            CALL SYMBOL(X1,DY(1),.14,3,0.0,-1)
            CALL DASHLN(0.14,0.14,0.14,0.14)
            CALL PLOT(X2,DY(2),4)
            CALL SYMBOL(X2,DY(2),.14,3,0.0,-1)
            CALL PLOT(X3,DY(3),4)
            CALL SYMBOL(X3,DY(3),.14,3,0.0,-1)
            XX= X3 + .25
            CALL SYMBOL(XX,DY(3),.14,'DISCRETE',0.0,8)
```

```
$LIST P551:GRAPH3(*F)
      C     PROGRAM TO PLOT GRAPH 3 FOR THESIS DATA
      C
            REAL SY(3), DY(3), MY(3), X(3),Y(3), DUM(3)
            READ(5,101) (SY(I), I=1,3)
            READ(5,101) (DY(I), I=1,3)
            READ(5,101) (MY(I), I=1,3)
            WRITE(6,102) (SY(I), I=1,3)
            READ(5,101) (DUM(I), I=1,3)
            WRITE(6,102) (DY(I), I=1,3)
            WRITE(6,102) (MY(I), I=1,3)
            X1 = .5
            X2 = 2.5
            X3 = 4.5
            X(1)=0.0
            X(2)=6.0
            Y(1)=0.0
            Y(2)=0.0
            CALL SCALE(DUM,3,8.0,XMIN,DX,1)
            WRITE(6,103) XMIN,DX
        103 FORMAT('0',2F8.3)
            DO 10 I=1,3
            SY(I) = (SY(I) - XMIN)/DX
            DY(I) = (DY(I) - XMIN)/DX
            MY(I) = (MY(I) - XMIN)/DX
         10 CONTINUE
            WRITE(6,102) (SY(I), I=1,3)
            WRITE(6,102) (DY(I), I=1,3)
            WRITE(6,102) (MY(I), I=1,3)
            CALL SYMBOL(2.0,9.0,.28,'FIGURE 5',0.0,8)
            CALL SYMBOL(1.5,8.25,.14,'HYPOTHESIZED ITI BY P INTERACTIO
            CALL PLOT(0.0,0.0,3)
            CALL PLOT(0.0,7.5,2)
            CALL SYMBOL(-0.5,2.0,.21,'REACTION TIME (MSEC)',90.0,20)
            CALL SYMBOL(0.0,7.5,.14,6,0.0,-1)
            CALL LINE(X,Y,2,1)
            CALL SYMBOL(X1,0.0,0.07,13,0.0,-1)
            CALL SYMBOL(X2,0.0,0.07,13,0.0,-1)
            CALL SYMBOL(X3,0.0,0.07,13,0.0,-1)
            CALL SYMBOL(X1,-.21,.14,'P',0.0,1)
            CALL SYMBOL(X3,-.21,.14,'P',0.0,1)
            CALL SYMBOL(.6,-.25,.07,'.67',0.0,3)
            CALL SYMBOL(2.6,-.25,.07,'.50',0.0,3)
            CALL SYMBOL(4.6,-.25,.07,'.33',0.0,3)
            CALL SYMBOL(2.0,-.5,.21,'PROBABILITY',0.0,11)
            CALL SYMBOL(X1,SY(1),.14,30,0.0,-1)
            CALL DASHLN(0.07,0.07,0.07,0.07)
            CALL PLOT(X2,SY(2),4)
            CALL SYMBOL(X2,SY(2),.14,30,0.0,-1)
            CALL PLOT(X3,SY(3),4)
            CALL SYMBOL(X3,SY(3),.14,30,0.0,-1)
            XX= X3 + .25
            CALL SYMBOL(XX,SY(3),.14,'SERIAL',0.0,6)
            CALL SYMBOL(X1,DY(1),.14,3,0.0,-1)
            CALL DASHLN(0.14,0.14,0.14,0.14)
            CALL PLOT(X2,DY(2),4)
```

```
              CALL SYMBOL(X2,DY(2),.14,3,0.0,-1)
              CALL PLOT(X3,DY(3),4)
              CALL SYMBOL(X3,DY(3),.14,3,0.0,-1)
              XX= X3 + .25
              CALL SYMBOL(XX,DY(3),.14,'DISCRETE',0.0,8)
              CALL SYMBOL(X1,MY(1),.14,4,0.0,-1)
              CALL SYMBOL(X2,MY(2),.14,4,0.0,-2)
              CALL SYMBOL(X3,MY(3),.14,4,0.0,-2)
              XX= X3 + .25
              CALL SYMBOL(XX,MY(3),.14,'MEAN',0.0,4)
              CALL PLOTND
      101     FORMAT(3F6.1)
      102     FORMAT(' ',3F6.1)
              STOP
              END
     $DATA
END OF FILE


$COPY *SKIP
```

```
$LIST P551:GRAPH4(*F)
C     PROGRAM TO PLOT GRAPH 4 FOR THESIS DATA
C
        REAL SY(3), DY(3), MY(3), X(3),Y(3), DUM(3)
        READ(5,101) (SY(I), I=1,3)
        READ(5,101) (DY(I), I=1,3)
        READ(5,101) (MY(I), I=1,3)
        WRITE(6,102) (SY(I), I=1,3)
        READ(5,101) (DUM(I), I=1,3)
        WRITE(6,102) (DY(I), I=1,3)
        WRITE(6,102) (MY(I), I=1,3)
        X1 = .5
        X2 = 2.5
        X3 = 4.5
        X(1)=0.0
        X(2)=6.0
        Y(1)=0.0
        Y(2)=0.0
        CALL SCALE(DUM,3,8.0,XMIN,DX,1)
        WRITE(6,103) XMIN,DX
  103   FORMAT('0',2F8.3)
        DO 10 I=1,3
        SY(I) = (SY(I) - XMIN)/DX
        DY(I) = (DY(I) - XMIN)/DX
        MY(I) = (MY(I) - XMIN)/DX
   10   CONTINUE
        WRITE(6,102) (SY(I), I=1,3)
        WRITE(6,102) (DY(I), I=1,3)
        WRITE(6,102) (MY(I), I=1,3)
        CALL SYMBOL(2.0,9.0,.28,'FIGURE 6',0.0,8)
        CALL SYMBOL(1.5,8.25,.14,'HYPOTHESIZED ITI BY COND INTERACT
        CALL PLOT(0.0,0.0,3)
        CALL PLOT(0.0,7.5,2)
        CALL SYMBOL(-0.5,2.0,.21,'REACTION TIME (MSEC)',90.0,20)
        CALL SYMBOL(0.0,7.5,.14,6,0.0,-1)
        CALL LINE(X,Y,2,1)
        CALL SYMBOL(X1,0.0,0.14,13,0.0,-1)
        CALL SYMBOL(X2,0.0,0.14,13,0.0,-1)
        CALL SYMBOL(X3,0.0,0.14,13,0.0,-1)
        CALL SYMBOL(X1,-.25,.14,'AE',0.0,2)
        CALL SYMBOL(X2,-.25,.14,'RE',0.0,2)
        CALL SYMBOL(X3,-.25,.14,'DRE',0.0,3)
        CALL SYMBOL(2.0,-0.5,.14,'CONDITION',0.0,9)
        CALL SYMBOL(X1,SY(1),.14,30,0.0,-1)
        CALL DASHLN(0.07,0.07,0.07,0.07)
        CALL PLOT(X2,SY(2),4)
        CALL SYMBOL(X2,SY(2),.14,30,0.0,-1)
        CALL PLOT(X3,SY(3),4)
        CALL SYMBOL(X3,SY(3),.14,30,0.0,-1)
        XX= X3 + .25
        CALL SYMBOL(XX,SY(3),.14,'SERIAL',0.0,6)
        CALL SYMBOL(X1,DY(1),.14,3,0.0,-1)
        CALL DASHLN(0.14,0.14,0.14,0.14)
        CALL PLOT(X2,DY(2),4)
        CALL SYMBOL(X2,DY(2),.14,3,0.0,-1)
        CALL PLOT(X3,DY(3),4)
```

```
              CALL SYMBOL(X3,DY(3),.14,3,0.0,-1)
              XX= X3 + .25
              CALL SYMBOL(XX,DY(3),.14,'DISCRETE',0.0,8)
              CALL SYMBOL(X1,MY(1),.14,4,0.0,-1)
              CALL SYMBOL(X2,MY(2),.14,4,0.0,-2)
              CALL SYMBOL(X3,MY(3),.14,4,0.0,-2)
              XX= X3 + .25
              CALL SYMBOL(XX,MY(3),.14,'MEAN',0.0,4)
              CALL PLOTND
        101   FORMAT(3F6.1)
        102   FORMAT(' ',3F6.1)
              STOP
              END
       $DATA
END OF FILE


$COPY *SKIP
```

APPENDIX D

RAW Data

LEAF 100 OMITTED IN PAGE NUMBERING.

```
$COPY TRIAL1
 311 307-309-329 304 312-331 335 306-344 241-274 262 362 308-299  01111 01
 229-265 999 390-339-338 337 353-311-325-258 273 266-268-328 315  01111  2
-333 317-211-317 372-370 357 384-355-466-307 385 382 410-338-318  01111  3
 333 365 390-324-327-296-260 999 358-365-266 409 326-387-380-391  01111  4
 388 344 295-266-310 379 333-330-328-331 422 333 368-259-326-270  01111  5
-330 330 248-325-270 277 276 376 368-387 372-338 279-279 328 999  01111  6
 301 272 272-356-213 285 254 263 266-333 303-402 311-329-431 390  01111  7
 322-349 274-348-345 312 272-268-311 418 278-367-386-341 329 261  01111  8
 342-332 476-240 409-369-235 387 246-392-253-276 223-277 196 477  01111  9
 265 265-379 344 364 270-363-328-296-302 999 244 249-323-302 340  01111 10
 241-392 252 332 254-399-332-306 310-522-331-249-296 326 264-406  01111 11
-293-279-249 348 288-383-299 390 241 331 341-407-224-238 999 999  01111 12
 314 357 519 373 312 337-329 293-346 999 304 299 284-364-266 333  01111 13
 396-422-244-295-387 361 380 317-426-259-343 366 299-310-346 999  01111 14
 307 270-402-336 392 246-331-197-259 417 274 308-447-264-337-328  01111 15
 438 274 236-397-223 459 301 329 309-310 137 323-464 221 370-393  01111 16
-333 318 296 547-417-341 375 313-387-275-315 434 256-388-252 353  01111 17
 267-621-313 380-466 386 298 431-364-281-574 359 308 358 354 999  01111 18
-290 408-492 350-398-633 285 318 304 283 273 268 252-354 315-451  01111 19
 272 326 287 282-346 320 301 290 312 293-415-295 427 304 390-300  01111 20
-320 326-461-267-306-317 380 235-532-309 352 349 316-381-308 414  01111 21
 306 589-409 338-366-416 310 340 367-319-360 369 352-363-318-355  01111 22
-508 379 325 330 325 330 325-413-206-196 394 297 999-348 377-429  01111 23
-359-620 349 343-400-291-277 381 292 278-387-281-383-305 385 999  01111 24
 288-446 271 349-377-347 300 255 264 264-393-352 312 276 354-313  01111 25
-501-293 441 316 292-320 999-281 273 417 287-271-342 386 316-364  01111 26
-355-299 298 321-386-290 376 355 330-370-291-341-297-288 362 290  01111 27
-407-256 401 314 354-378-281 349-536 341-287 292-387-396 344 340  01111 28
 439-376-507 354 306-327-269-267 459 274-404-341 429 354-377-623  01111 29
-301-461 374 353 311-323-425 310 423 400 352 320-383 300 296 999  01111 30
-340 352 262 228 240 316 314 320-369 277-364 302 275 261 295-250  02121  1
 341 316 261 214 206 999 339 297-555-411 317-388-258-232-306 327  02121  2
 316-367-353 288-650 368-397 281-226-287 354 379 320-243-288 365  02121  3
 283-393-305-314-284-323 352 293 323-455-290 306 291-353-324-302  02121  4
 287 288-399-262-279 300 276-426-327-308 405 313 320-282-340-325  02121  5
-142 356 257-332 347 330-386 266 330-421-310 342 383 999 361 999  02121  6
 288-275 302-303-291 262-208 370 315-389-309 341 312-302-351-283  02121  7
-293 309 316-386-313-337-202 334-301-256-284 374 292 316-429-323  02121  8
 306 286-381-322 298 341 267 302-362-311-231-264 280 286 268-313  02121  9
-285 249 247-389-313 278-334 260-354 312-351-325-308 281-338 265  02121 10
-270 308 226 309-364-635-281 311-371-285-296 287 287-273-284 279  02121 11
 287 830 318-374-257 315 792 273 233-346 228 383 327 302 259 999  02121 12
 361 320 305 253-301 388 309 999-361 339-321 300 349 307 417 288  02121 13
-386 290-379 264-404-299 294 335-345 295-362-286 277 288-204-238  02121 14
 318 286-301-301-655 322 537 369-382 316-443 290-430-295-383 322  02121 15
-309 318-362 327-338-301 326 317 223-265-247 999 999 271-362-306  02121 16
-318-281 367 280 294 335-331-346 392 285-374-327 335 339 338-273  02121 17
-333-325 305-437-287-332-296 321 294-395-228-331-299 338 314 999  02121 18
-288-331-299 338 314-395-372 657 305 290 331-386-331 336-370 356  02121 19
-304 290 289 304 305 999 281 306-367 315-382 296 310 275 371 319  02121 20
-292 403-410 349-397-369 264 323-290 318-278-250 281 308-354-346  02121 21
 279 311-264-290-299 293 510 301-316 342-437 320-395-328-300 310  02121 22
-332 368-380 380-290-294 295 309 269-234 425 451 303-300-294-340  02121 23
-386 296 260 375 322-328-325 285 266 999 324 298 269-294-322 999  02121 24
 432-376-339-300-309 421 299-355-239-314-316 304 307-360-343 330  02121 25
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 305 313 303-356-264 341-402 383-388 325 326 348 288 999 304-347  02121 26
-355-310 342 311 340 339-383-323 438 319-324-302-251-335 320 323  02121 27
 314-300-311-308 343 328-312 475 293-331 295-414-317-251 486 321  02121 28
-388-288 359 284 331-293-308-342-331-286 999 313-408-385 317 337  02121 29
 402-297 323 309 282-408-307-303 999-327 331 303 276 999-486 999  02121 30
-534 452 336 461 378 340-449 380-410 381 387-383 321 374 319 386  03134  1
-422-526-396 373-376 293 493-320-374 375 330-383 336-347 318-341  03134  2
 331 359 360 387-372 311 366 335 341 355-396 363 308 380-423 353  03134  3
 337 381 360 342 373-380 359-596 425 390-438 333-372 425 433 304  03134  4
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