A RESPONSE SELECTION MODEL FOR CHOICE REACTION TIME

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FOR

CHOICE REACTION TIME

By

ALBERT DOUGLAS TINDALL, M.A.

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AUTHOR: Albert Douglas Tindall, B.A. (University of British Columbia)

M.A. (University of British Columbia)

SUPERVISOR: Dr. S. W. Link

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SCOPE AND CONTENTS:

The binary choice Fast Guess Model of Ollman and Yellott was generalized to a multiple choice model and six subjects were run in a choice reaction time task to test the model. Stimulus set sizes of two, four and six were used and response accuracy and speed motivation was manipulated through specific instructions which were changed from trial to trial. Three different motivational instructions were used. In all cases, subjects were to respond with maximum accuracy but were also told on each trial to either disregard the duration of their response, respond within 440 milliseconds or respond within 300 milliseconds.

The generalized Fast Guess Model was rejected because response time parameters of the SCR state were found to change across response accuracy-speed motivation instructions and across stimulus set sizes. Implications of these results for other classes of models were also discussed.

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Finally, I dedicate this work to my daughter, Nicole, and fully appreciate that it in no measure compensates for the time which we have not been able to share.

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CHAPTER ONE

Introduction

While experimenters have been interested in how rapidly humans can respond to simple environmental changes for over one hundred years, little adequate theory has resulted. Two general theoretical approaches have dominated the field of response time. These approaches will be referred to as convolution theories, represented by the work of Donders (1868), Hick (1952) and Sternberg (1963, 1964, 1966, 1969a, b) and sequential processing theories, represented by the empirical and theoretical developments of Edwards (1965), Fitts (1966), Laming (1968) and Stone (1960). Recently a third theoretical approach has been made to the study of response time. This class of theories is referred to as mixture theory and is represented by the research of Falmagne (1965), Falmagne and Theios (1969), Link and Tindall (1970, 1971), Ollman (1966, 1970) and Yellott (1967, 1971).

The convolution theories are of limited applicability because they have only been developed for accurate performance and do not generate errors. The sequential processing theories of Stone (1960) and Laming (1968) predict that correct and error response latencies for a given response must be equal. Since most experimental findings fail to corroborate the prediction of equal mean correct and error response latencies, the sequential processing theories proposed by Stone and Laming must be rejected. Recent developments in mixture theories circumvent the shortcomings of both convolution and sequential processing theories. For example the theories proposed by Ollman (1966) and

Yellott (1971) specify that errors are in part the result of guessing and permit the latencies of error responses to be different from those of correct responses. The models developed within the mixture theory framework offer an alternative explanation to the sequential processing theories for how the subject operates in tasks in which he must trade response speed against response accuracy. The research reported here is designed to investigate some general mixture models. Either support for the mixture models or the particular nature of their failures will have implications for the convolution and sequential processing theories.

<u>Historical Background</u>

Convolution Theories

Convolution theories are the oldest class of theories of response time, RT. The conceptualization of response time as a sum of a number of subcomponents began when experimenters became interested in measuring the time which humans took to perform various tasks (Wundt, 1862, 1863; Donders, 1868). Donders believed that response latency if appropriately analyzed would permit one to estimate the time required to complete the mental events which he believed to underlie some human thoughts.

Donders proposed three classes of experiments which he believed were sufficiently simple that one could intuit the number and nature of mental events involved. The first experiment, referred to as a choice reaction time task (CRT), consisted of discrete trials in which one of two possible stimuli was presented to a subject. Each stimulus was mapped onto a distinct response. The stimulus for each trial was randomly determined and the subject had to decide as quickly as possible which stimulus was presented and indicate his choice with depression of the appropriate response key. Mental events believed involved in this task were stimulus categorization or recognition, response selection and response execution. During stimulus categorization, the stimulus was assumed to be decoded, analyzed then compared with memory representations of the possible stimulus events. The categorization process would terminate with classification of the stimulus. Response selection began when stimulus categorization was completed. Output of the categorization stage was used by the response selection stage to determine the appropriate response. Finally, response execution consisted of events involved in performing the selected response. Response execution might include coordinating muscle movements, ensuring sufficient speed and accuracy of the motor acts, etc. The second task proposed by Donders was different than the first because only one response was required. Two stimuli were again presented randomly on discrete trials. If one of the stimuli occurred, the subject was required to press a response key. If the other, he was to withhold his response. This task was believed to involve only stimulus categorization and response execution events. Donders claimed response selection was not necessary since only one overt response was possible. Finally, the third task, referred to as a simple reaction time task, required only that the subject press a key when either stimulus was presented. This task was believed to involve only response execution.

Two aspects of Donders' analysis of mental events involved in these experimental tasks are important (Sternberg, 1969a,b). The first is the assumption of three distinct mental events: stimulus categorization, response selection and response execution. The second assumption is that times required to complete these events are nonoverlapping. Donders' interpretation of his experiments and these assumptions led him to propose a subtractive method for estimation of time to complete each of the three mental events.

The subtractive method was subject to considerable criticism (Ach, 1905 and Watt, 1905 as cited in Woodworth, 1938). It was maintained that the hypothesized components were not invariant across experimental tasks. The subject was able to prepare himself to a higher pitch of readiness in simple reaction time tasks than in CRT tasks. Therefore, the response execution process was not identical across tasks. 'Though in the stimulus categorization task the subject had only one overt response to make, he had to decide whether to respond. This decision process was effectively response selection. Furthermore, it was claimed that response selection overlapped in time with stimulus categorization and could not be estimated by subtraction. While stimulus categorization was occurring, partially completed classification could be used by the response selection process to begin selecting the response which at that stage of processing would be appropriate. Although criticisms were directed largely at the interpretation of the experiments used to test the theory, the effect was a subsequent rejection of the experimental method as well as the theoretical assumptions. For a time, response latency was considered to offer little indication of underlying processes of choice behavior.

The introduction of information theory concepts into psychology (Shannon and Weaver, 1949) led to a revival of interest in response latency as well as the use of concepts similar to Donders' subtractive method. Hick (1952) was interested in the relationship between stimulus uncertainty and response latency. Experiments in which highly discriminable stimuli were mapped onto a set of distinct responses revealed that response latency increased monotonically with number of possible stimuli. In addition to the analysis of his own results, Hick (1952) reanalyzed earlier data (Merkel, 1885; Blank, 1934). He found the relationship between average stimulus uncertainty, which was manipulated by varying the number of stimuli, and response latency was approximately linear. The relationship between average uncertainty and response latency has been referred to as Hick's Law and is expressed as:

$$\text{Mean CRT} = K \log n+1$$

where n refers to the number of equiprobable stimuli and K is a constant. Numerous models were developed which attempted to account for this relationship between average uncertainty and response latency (e.g. Hick, 1952).

Hick (1952) proposed two general classes of models: template matching (TM) and feature testing (FT) models. These models were designed to represent the recognition process in CRT. The recognition process was assumed to consist of two subprocesses, a preprocessing component and a categorization component. Preprocessing referred to a substage of stimulus recognition in which the stimulus representation was prepared for comparison in the categorization stage. For the TM models, Hick (1952) assumed that the subject maintained in memory representations of the alternative stimuli and that when a stimulus was presented one or more replicates of its template were generated in the preprocessing stage. These templates were matched against alternatives in memory during the categorization stage. With regard to FT models, Hick (1952) assumed that each stimulus alternative was represented in memory by a list of features and that when a stimulus was presented one or more replicates of its feature list were generated in the preprocessing stage. These replicates were compared against feature lists of the alternatives during categorization. For both TM and FT models, Hick proposed special cases in which comparisons made in the categorization stage were either simultaneous (the stimulus was compared with all possible alternatives concurrently) or serial. Also, generation of replicates of the stimulus (templates or feature lists) in the preprocessing stage could be either simultaneous, serial or self-replication (first replicate splits into two identical copies each of which again splits in two, etc.). Other authors have elaborated upon versions of these models (e.g. Christie and Luce, 1956; Rapoport, 1959; Sternberg, 1963, 1964, 1966).

Generally, these models have focussed upon stimulus categorization and ignored response selection and execution. However, since number of stimuli and responses were identical, in these early experiments, it would seem that models which take account of stimulus categorization only are inappropriate. Falmagne (1965) and Kornblum (1969) demonstrated that to some extent increase in RT as a function of stimulus set size is due to fewer occurences of repetitions of stimuli or to longer sequences of trials before a stimulus is repeated with large stimulus sets. Furthermore, Bertelson (1965) and Bertelson and Renkin (1966) in serial choice reaction time tasks showed that most of the repetition effects observed in CRTs are due to repetition of response not stimulus. All repetition effects, however, cannot be accounted for by the response. Laberge and Tweedy (1964) mapped two of three stimuli onto one response in a binary response task and found mean response time varied as a function of stimulus probability and stimulus value when the response factor was controlled.

Two recent reviews of the literature on response latency, Welford (1960) and Smith (1968), indicate that modern psychologists have retained some of Donders' ideas about response latency. Psychologists have adopted the assumption that response latency is composed of durations of certain mental events which are involved in choice behavior. In modern terminology, these mental events are referred to as processing stages or simply stages. These stages are again assumed to occur during the time interval between presentation of a stimulus and occurence of a response to that stimulus. The stages of which choice behavior is now assumed to consist are often referred to as transducer, stimulus categorization, response selection and response execution. The last three stages are identical to those proposed by Donders (1868). The transducer stage refers to events and time required to convert physical energy of the stimulus to physiological events utilized in the unknown processes of stimulus categorization. While modern experimental psychologists have adopted Donders' assumptions regarding underlying mental processes of response behavior, most have not accepted without question the assumption that these events do not overlap in time.

Researchers (e.g. Morin and Forrin, 1963; Nickerson and Feehrer, 1964) have attempted to study either stimulus categorization or response selection. They have substituted many stimuli to few responses or few stimuli to many responses for usual one to one stimulus-response mappings. In experiments involving few stimuli mapped to many responses, each stimulus was mapped to one or more responses. Subjects were instructed to indicate a particular stimulus by randomly choosing among the set of appropriate responses for that stimulus. It was suggested (Smith, 1968) that longer response times which are associated with larger response sets per stimulus might have resulted from subjects' attempts at random selection from the response set. As set increased in size, memory load would be greater if subjects consciously tried to respond randomly. It was hoped manipulations of size of stimulus or response set would introduce expanded processing in either the stimulus categorization or response selection stage and that quantitative changes in response latency would indicate the nature of the processes of a particular stage.

More recently, Sternberg (1969a) has suggested that processes underlying response latency might be investigated if procedures were developed to selectively affect components of a single stage but leave other possible overlapping stages unaffected. These selective procedures might reveal properties and limitations of a particular processing stage. An understanding of properties and limitations of one stage would be valuable for future considerations of how that processing stage is linked with others.

Sternberg (1969a) has presented experiments designed to investigate the recognition stage. To remove confounding of recognition and response selection processes inherent in Hick's experiments, in Sternberg's experiments, the response was always one of two possible choices while number of stimuli was varied. For each condition of the experiments, N stimuli were defined as belonging to a positive set, for example, a subset of the digits 1, 2, ..., 8. During an experiment, subjects were presented single digits and asked to make one response if the digit belonged in the positive set and another if it did not. Sternberg examined response latency as a function of the number of elements in the positive set. The relationship between latency and set size was linear.

His experiments led Sternberg (1969a) to propose a serial search process in which the search is an exhaustive scan of all items in the positive set, assumed to be stored in active memory. The exhaustive serial search process led to the prediction that increases in set size would produce linear increases in RT. Sternberg (1969a) also argued that his experiments provided a situation in which components of a single stage of processing were affected without insertion of additional stages. In terms of his serial search model. Sternberg assumed that each increase in number of items in the positive set required an additional comparison in the recognition stage.

In summary, according to all convolution theories, RT is composed of a sum of durations of components of choice behavior. For Donders (1868), the components of interest were the stages of stimulus recognition, response selection and response execution. Hick (1952), in variations of the TM and FT models, proposed that the additive components represented time required to produce replicates in the preprocessing stage of recognition and/or time required to compare replicates with stored representations in the categorization stage of recognition. Sternberg

(1969a) has focussed upon the comparison process in the recognition stage. He has assumed that the additive components consist of the durations for each of the comparisons between the stimulus and memory representations of the possible alternatives.

In all of the above models, accurate performance is required and no provision is made for errors. In order to force subjects to comply with these models, the occurence of errors is reduced by encouraging subjects to be accurate or penalizing them for errors. To ensure a high level of confidence, subjects may make a series of passes through the recognition process rather than a single pass before they execute a response. Each pass through the recognition process could result in a covert choice. Perhaps, the relationship between response time and stimulus set size reflects, in part, the number of additional covert choices an accuracy-oriented subject must make before he is confident enough to make a response. This possibility has not been entertained in the models proposed by Hick (1952), Rapoport (1959) or Sternberg (1963, 1964, 1966, 1969a,b). If any multiple choice behavior does occur and is a function of stimulus set size, response latency will not be a reliable indicator of the events involved in a single pass through the recognition process.

Results obtained by Pachella and Fisher (1972) are consistent with a multiple pass type of process when subjects operate under an accuracy-oriented set. Pachella and Fisher (1972) used time deadlines and varied stimulus set size to test Hick's Law. A plot of information transmitted against median RTs for different stimulus set sizes revealed that rate of transmission was constant across time deadlines: 300, 400 and 700 milliseconds but lower under accuracy instructions. Pachella and Fisher (1972) were critical of the convolution theories because they do not make explicit statements about the form of the speed-accuracy relation. Also, Pachella and Fisher (1972) were critical of the sequential processing theories and mixture theories, discussed below, because although they predict speed-accuracy relations, they have only been developed for binary choice tasks. It was suggested that either the convolution theories must be modified to account for speed-accuracy relations or the sequential processing and mixture theories must be extended beyond the limitations of the two-choice task.

Sequential Processing Theories

The sequential processing theories (e.g. Edwards, 1965; Laming, 1968; Stone, 1960) were developed from Wald's theoretical presentation of sequential analysis (Wald, 1947). Sequential processing theories of CRT have been limited to binary choice tasks with the exception of a special case developed recently by Laming (1968). In the first sequential processing model of CRT, Stone (1960) assumed that when a stimulus was presented, it gave rise to an information stream, continuous in time. The subject was assumed to sample from this information stream and to calculate the likelihood that the sample originated from either one stimulus alternative or the other. Further, the subject was assumed to take the logarithm of the ratio of the likelihoods. Each time the subject sampled from the information stream a log likelihood ratio was calculated. The log likelihood ratios of successive samples were assumed to be added together until the accumulated total either exceeded some predetermined value, the decision criterion for one response, or fell below some other predetermined value, the decision criterion for the other response. When a decision criterion was crossed the appropriate response occurred. This model was represented as a random walk over time along the decision axis of log likelihood ratio.

In the sequential processing models (Edwards, 1965; Laming, 1968; Stone, 1960) a tradeoff between the speed and accuracy of responses is obtained by adjustments in the position of the decision criteria. If the decision criteria are moved in towards the starting point, fewer samples are necessary before one of the decision criteria is crossed. Therefore, RT decreases while error rate increases. If the decision criteria are moved out away from the starting point, more samples are necessary before a decision criterion is crossed. Hence, RT increases while error rate decreases.

The sequential processing models also predict a relationship between stimulus discriminability and RT. When two stimulus alternatives are made more similar, the likelihood that any sample from the stimulus information stream could have arisen from either of the alternatives approaches .5. Therefore, as alternatives are made more similar, the log likelihood ratio for samples from the information stream approaches zero and more samples are needed before a decision criterion is reached. Hence, as the stimulus alternatives are made more similar, RT increases.

One difficulty with the models of Stone (1960) and Edwards (1965) is that the mean RTs for correct and error responses are identical. Fitts (1966) has suggested that this difficulty can be overcome if one assumes that the decision criteria are variable and shift in and out. Noisy decision criteria would produce error RTs which were shorter than correct RTs. Laming (1968) has proposed a modification which also permits error RTs to be faster than correct RTs. He assumes that subjects may begin sampling information before a stimulus has actually been presented and therefore sample only from a noise distribution.

Another difficulty with the random walk model is that the statistical theory necessary for a general multiple choice model has not been developed. Laming (1968) has developed a multiple choice random walk model. The mathematical complexity of this model limits its usefulness as a basis for more comprehensive formulations.

Mixture Theories

The mixture theories (Falmagne, 1965; Falmagne and Theios, 1969; Link and Tindall, 1970, 1971; Ollman, 1966, 1970; Yellott, 1967, 1971) were first developed by Falmagne (1965) to account for repetition effects in serial choice reaction time. Falmagne (1965) proposed that subjects in a serial CRT task could be represented as being in one of two states on any trial. Subjects could on a given trial either be in a ready state, in which they were prepared for the particular stimulus which was presented on that trial, or in a nonready state, in which they had to reactivate the processes necessary for the particular stimulus . Response time from the ready state was assumed to be less than from the nonready state. Falmagne (1965) assumed that occurence of a stimulus resulted in subsequent readiness for that stimulus. On an ensuing trial, if the stimulus were repeated RT would be short. If the stimulus were not repeated, with some probability the subject would change to a nonready state for that stimulus. Falmagne (1965) represented RT in the serial CRT task as consisting of a binary mixture of short times from the ready state and longer times from the nonready state. Falmagne and

Theios (1969) extended the mixture theory, again for serial CRT tasks, to represent RTs as mixtures from three states: selective attention, immediate memory and long term memory states.

Ollman (1966) proposed a two state (Fast Guess) model for discrete trial CRT tasks. He suggested that responses could be represented as coming from either a recognition process in which the stimulus was analyzed or a fast guessing process in which no stimulus information was utilized. Yellott (1967, 1971) elaborated upon the Ollman (1966) Fast Guess Model and showed that it was possible to obtain estimates of the mean latency of the recognition process (Yellott, referred to it as an SCR, stimulus-controlled response). In all of the above choice experiments (Ollman, 1966; Yellott, 1967, 1971), estimates of the mean latencies of the SCR state were invariant under changes produced by variations in motivation for response speed and variations in stimulus probability.

Current Research

Recently, Link and Tindall (1970, 1971) have presented a series of experiments designed to investigate the properties of response latency in choice reaction time tasks in which subjects are encouraged to vary response speed. They used the method of time deadlines, employed previously by Fitts (1966), to manipulate subjects' response times.

In a series of experiments, Link and Tindall (1970, 1971) demonstrated that subjects are able to vary their response times to comply with restrictions of time deadlines. Mean response times remained relatively stable across experimental sessions for particular time deadlines and mean response time did not change as a function of recognition difficulty within a time deadline although accuracy was affected. This latter result cannot be easily explained by the sequential processing models. The likelihood ratios for highly recognizable alternatives would be larger than for less recognizable ones. The decision criteria would, therefore, be reached much sooner for recognizable stimuli. The sequential processing models would, hence, predict shorter mean RTs for more easily recognizable stimuli.

In some discrimination tasks, pairs of stimuli were presented on discrete trials with the members of each pair presented successively. The subject was required to indicate whether the first stimulus in the pair was the same as the second. When the time interval between the first and second stimulus of a pair was varied, a memory decay of the first stimulus, similar to that demonstrated by Kinchla and Smyzer (1967), was found. However, the mean response time of the discrimination did not change as a function of interstimulus interval, although the response probability varied in a systematic fashion (unpublished). The sequential processing theories cannot easily account for these results. Again as above, if it is assumed that memory decay of the first stimulus produces less discriminable alternatives, then in terms of the sequential processing theories the absolute value of the log likelihood ratios for information samples would be inversely related to interstimulus interval. Therefore, mean RT should increase with interstimulus interval. Also, Link and Tindall demonstrated that subjects are capable of varying the speed of their responses from trial to trial with no apparent residual effects of the deadline of the previous trial (unpublished).

In the model proposed by Link and Tindall (1970), response latency was assumed to be a mixture of response latencies from what was referred to earlier as a stimulus-controlled response, SCR, state and latencies from a guessing state. This model was an elaboration of the Fast Guess Model presented by Ollman (1966) and Yellott (1967, 1971). Derivations from this model permitted one to estimate parameters of the latency distributions from the SCR and guessing states (see Link and Tindall, 1970).

In the experiments referred to above (Link and Tindall, 1970, 1971; Ollman, 1966, 1970; Yellott, 1967, 1971) subjects' response times were altered by the use of time deadlines. It was assumed that subjects could control their response times by manipulating the proportion of trials in which they responded from the SCR or the guessing states. The latency distribution of the SCR state was assumed to remain invariant across time deadlines. Link and Tindall wished to determine whether subjects did indeed merely alter the proportion of guessing trials across time deadlines or whether the latency distribution of the SCR state was altered.

In all of their experiments, Link and Tindall rejected the hypothesis of invariance of the SCR latency distribution. They found that the latency distribution tended to shift toward smaller values as the time deadlines decreased. This result is in contradiction to the results of Ollman (1966) and Yellott (1967, 1971). It was also interesting that the latency distributions within time deadlines did not shift across changes in stimulus discriminability produced by changes in stimulus similarity and interstimulus interval. This observation would suggest that any proposals to modify the mixture theories to include a sequential processing mechanism in the SCR state would also have to provide decision criteria which can be adjusted to trade the size of the log likelihood ratio off against distance between the initial point of the random walk and the decision criteria.

The above results are important with regard to the TM and FT models mentioned earlier (Hick, 1952; Rapoport, 1959; Sternberg, 1963, 1964, 1966). As was noted, these models do not allow for errors. In particular, they do not have a mechanism which might allow for the speed-accuracy tradeoffs which have been observed (Smith, 1968). It might be argued that if these models were modified so that TM or FT processes occurred in what was called the SCR state then speed-accuracy relationships could be accommodated. Errors would be produced from the guessing state, while the SCR state would produce error-free responses from the TM or FT processes. The results of Link and Tindall (1970, 1971) do not support this proposed interpretation. The latency distribution of the SCR state varies with time deadlines. To incorporate the changes in the latency distributions of the SCR state, the processes of TM or FT would have to be altered. For shorter time deadlines, some abbreviated or accelerated forms of stimulus processing would have to occur.

TM models which postulate a serial search might account for the changes in the SCR distribution, if the serial search could be assumed to abort on short time deadline trials. This explanation of an abbreviated process would be tenable for stimulus set sizes larger than 2. The experiments by Link and Tindall (1970, 1971), however, always utilized a stimulus set size of 2. For stimulus set size of 2, if the TM process is activated an alternative will be selected, either directly or by default. If the TM process is not activated, the result would be equivalent to entering the guessing state. Therefore, for set size 2, an accelerated form of processing seems to be required. However, in terms of the TM process, a partial analysis of an alternative is contrary to the notion of template matching. Smith (1968) has proposed that faster less accurate choices could be made by the TM process if the templates were assumed to be only rough approximations to the actual stimuli. He suggests that perhaps these simpler templates might be compared faster than more detailed ones. Smith (1968), however, argues that templates which are only rough approximations to the stimulus are contrary to the logic of TM and might better be considered as FT processes in which the feature lists are incomplete or the lists are only partially analysed. Furthermore, it is difficult to see how any empirical tests could differentiate between simplified templates and incomplete feature lists.

The results of experiments in which the latency distribution of SCRs remained invariant within a time deadline across changes in stimulus discriminability add further evidence for the above arguments regarding models. They indicate that within the SCR state, accuracy may be traded off with processing time since for decreased discriminability, probability correct decreases but processing time remains constant.

It would be of interest to investigate the relationship between mean latency of the SCR state and stimulus set size when time deadlines are imposed. The early experiments by Hick (1952), Hyman (1953) and

Crossman (1953) in which the number of stimuli was varied on one-to-one stimulus-response mappings, demonstrated a logarithmic relationship between CRT and set size. Sternberg (1969a), as noted above, demonstrated a linear relationship between set size and CRT when the response set was fixed at size 2. Since none of these experiments manipulated subjects' response times, the criticisms of the interpretations of these experiments which were expressed earlier, apply. The TM and FT models were proposed to account for the form of the relationship between CRT and stimulus set size. The manner in which the form of this relationship can be altered through the use of time deadlines will have implications for these models. For example, exhaustive serial searches which seem appropriate for accuracy-oriented tasks may have to be replaced by self-terminating searches for speeded tasks.

Also, it would be of interest to see whether variation in stimulus set size operated in the same way as variations in stimulus discriminability. Crossman (1955) proposed that the relationship between reaction time and stimulus set size was due to a decrease in discriminability produced by larger set sizes. Smith (1968) reviews the work of Sternberg (1964) and Chase and Posner (1965) who manipulated discriminability as well as set size. Sternberg (1964) decreased discriminability by adding a noise pattern to the stimulus. Chase and Posner (1965) increased stimulus similarity. Sternberg plotted RT against set size and found that the intercept of the line relating RT to set size increased when discriminability decreased. Similar plots by Chase and Posner revealed that for changes in stimulus similarity the slope of the function relating reaction time to stimulus set size increased as stimulus similarity increased. These results indicate that stimulus discriminability is not a unitary process and can be varied in at least two different ways each of which has its own effects upon the processing which underlies CRT. Since variations in stimulus similarity do affect the slope of the function relating CRT to set size then for very dissimilar stimuli, in theory, the slope should reach a zero limit. The argument that stimulus similarity is the variable which is responsible for the CRT-set size relationship seems to be supported. Furthermore, if stimulus similarity were the variable responsible for changes in CRT as a function of set size then according to the mixture theory the latency distribution from the SCR state should be invariant within a time deadline across changes in set size as was observed when stimulus similarity was varied directly (Link and Tindall, 1970).

It is not possible to conclude from the experiments by Link and Tindall (1970) that the recognition stage of processing is the only one affected by the manipulation of response time through time deadlines. In all of the experiments reported by Link and Tindall (1970, 1971) subjects were required to make a discrimination involving pairs of line segments of varying lengths. It might be assumed that many of these discriminations were relatively difficult and that the discrimination process would require a considerable proportion of the total response time. It may be the case, however, that the hypothesis of invariance of the SCR latency distribution with changes in time deadlines failed to hold up because the decision to use or to bypass the recognition as well as response selection stages was affected by variations in the time deadlines. If for example, imposition of moderately long time deadlines resulted in the subject's omission of the response selection process while imposition of even more stringent time deadlines resulted in further omission of the stimulus recognition process, the response latency distribution could not be represented by a binary mixture of invariant response latency distributions from one stimulus-controlled and one guessing state. The fact that the invariance hypothesis was apparently supported in some earlier experiments (Ollman, 1966; Yellott, 1967, 1971) in which highly discriminable stimuli were used is consistent with the above suggestion. In these earlier experiments, the recognition process may have required a very small proportion of the total RT and therefore not been susceptible to the effects of time deadlines. This argument will be pursued when the model and experiments below are summarized in the discussion.

In order to obtain more information about the response selection stage, the following model and experiment are proposed. In the conceptualization of this model and the design of the experiment we wish to assume that time to recognize the stimulus is minimal and that it will not be a significant factor in the total response time.

Response Selection Model (RSM)

Conceptually, the model is similar to the fast guess model proposed by Ollman (1966) and Yellott (1967, 1971) and extended by Link and Tindall (1970, 1971). Essentially, there are two classes of states in the model, a processor-controlled class and a guessing class. It is conceptualized that on every trial the subject enters the processor-controlled class with some probability, P, or enters the guessing class with some probability, 1 - P. The difference between this formulation and the earlier ones is that the earlier models allowed for only a binary response. This model will be developed generally for n responses, each associated with a distinct stimulus.

As was mentioned above, it will be assumed that recognition time is relatively short and unaffected by variations in time deadlines. That is, the subject is always assumed to complete the recognition process. The difficulty for the subject is assumed to occur when he attempts to enter the response selection process. It is assumed that response selection requires a relatively large amount of time, and that the subject can control his response time by avoiding the response selection stage and entering the guessing state. From the guessing state a response is output with a guessing bias. No assumption is made regarding overlap in real time of the recognition and response selection processes.

A general form of the model is presented in Figure 1 in the form of a probability tree diagram. The probability that stimulus i, S_i, is presented is represented by π_i. P_{ik} represents the probability of entering the response selection state given S_i when deadline k is in force, while $1 - P_{ik}$ represents the probability of entering the guessing state. a_{ijk} represents the probability that response j, R_j, is selected when S_i is presented while x_{ijk} is a random variable characterizing response time which represents the latency of response j from the response selection state when stimulus i is presented. The random variable x_{ijk} has a distribution L_{ijk} whose mean is M_{ijk}. b_{ijk} represents the probability that R_j is guessed when S_i is presented and y_{ijk} is a random variable which represents the latency of response j from the guessing state when stimulus i is presented. The random variable y_{ijk} has a distribution G_{ijk} whose mean is V_{ijk}.

Insert Figure 1

Several relationships can be derived for the general model. All of the following derivations will be for a fixed time deadline k. The probability of a correct response, given S_i, is equal to the sum of one component which represents the operations of the response selection state and one component which represents the operations of the guessing state. The response selection state component consists of the probability, P_{ik}, that the subject enters the response selection state times the probability, a_{iik} that he correctly selects R_i from the response buffer. The guessing state component consists of the probability, $1 - P_{ik}$, that the subject enters the guessing state times the bias probability, b_{iik}, that he guesses R_i given S_i. This relationship can be represented formally by:

$$Pc_i = P_{ik}a_{iik} + (1 - P_{ik})\, b_{iik}$$

The probability of a particular incorrect response, R_i, given S_j, is also equal to the sum of components from the response selection and guessing states. The response selection component consists of the probability, P_{jk}, of entering the response selection state times the probability, a_{jik}, that due to confusion in the response buffer, he wrongly selects R_i. The guessing state component consists of the probabil-

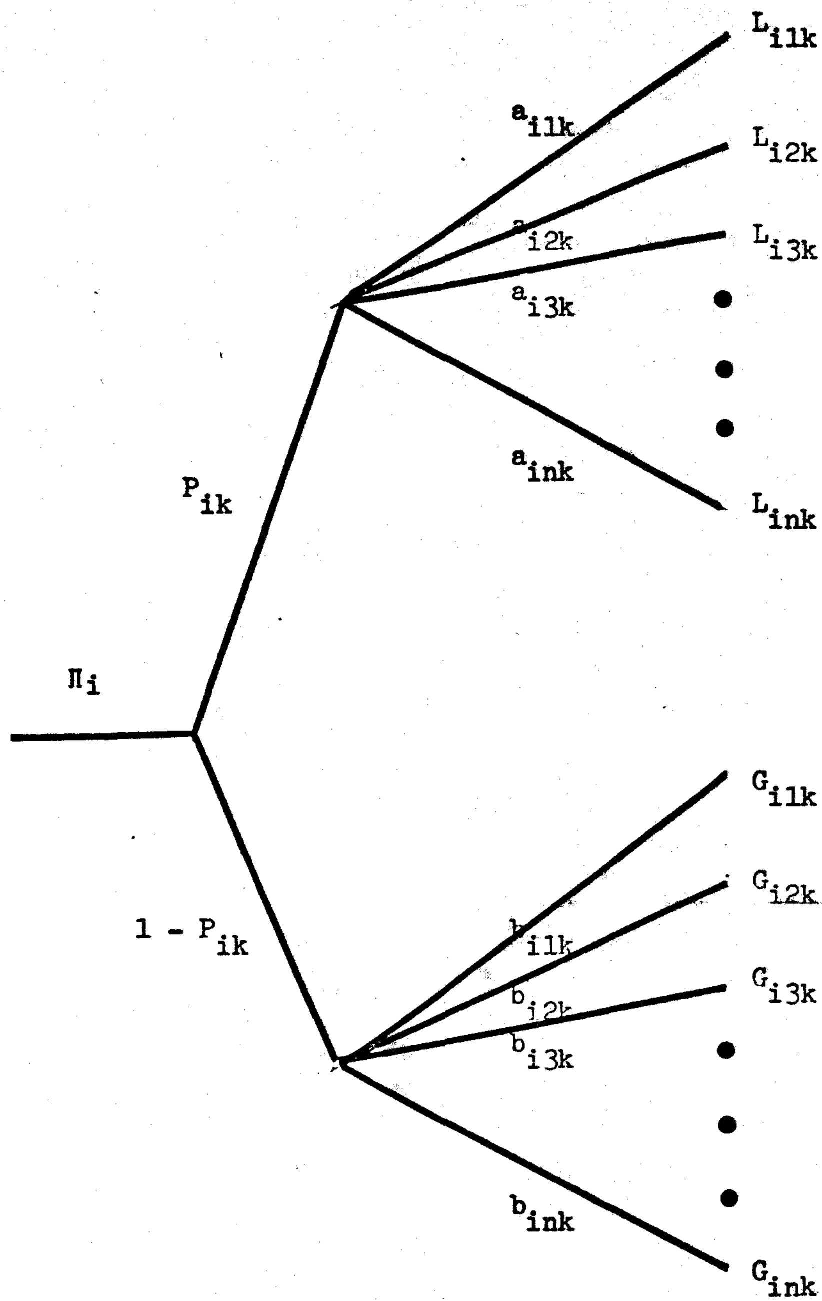

Figure 1. A probability tree representing the response selection model.

ity, 1 - P_{jk}, of entering the guessing state times the bias probability, b_{jik}, that he guesses R_i given S_j. Formally, this relationship can be represented by:

$$Pe_{ji} = P_{jk}\, a_{jik} + (1 - P_{jk})\, b_{jik}$$

Corresponding relationships for the observed conditional mean latencies can also be derived in a similar manner. Observed correct latency, given S_i, is equal to the sum of components from the response selection and guessing states. The response selection component consists of the probability, P_{ik}, of entering the response selection state times the probability, a_{iik}, that the correct R_i is selected from the response buffer times the latency, x_{iik}, of selecting R_i. The guessing state component consists of the probability, 1 - P_{ik}, that the subject enters the guessing state times the bias probability, b_{iik}, that he guesses R_i, given S_i, times the latency, y_{iik}, of guessing R_i given S_i. To normalize, the sum of these two components is divided by probability correct for R_i. Observed correct latency is therefore a random variable z_{iik} which is a mixture of the random variables x_{iik} and y_{iik}. The distribution of z_{iik}, F_{iik}, can be represented by:

$$F_{iik}(z) = (P_k\, a_{iik}\, L_{iik}\,(x) + (1 - P_k)\, b_{iik}\, G_{iik}\,(y))/Pc_i$$

The mean, Mc_i, of the observed correct latency distribution can be obtained by replacing the distributions in the above equation by the corresponding means.

$$Mc_i = (P_{ik}\, a_{iik}\, \mu_{iik} + (1 - P_{ik})\, b_{iik}\, V_{iik})/Pc_i$$

where μ_{iik} was defined as the mean of L_{iik} and V_{iik} the mean of G_{iik}.

Mean error latency for R_i, given S_j, can be obtained similarly:

$$Me_{ji} = (P_{jk}\, a_{jik}\, \mu_{jik} + (1 - P_{jk})\, b_{jik}\, V_{jik})/Pe_{ji}$$

where μ_{jik} was defined as the mean of L_{jik} and V_{jik} the mean of G_{jik}.

These equations are descriptions of the data in terms of the general formulation of the RSM but except for the conceptualization of a mixture of the SCR and guessing processes, the model lacks psychologically significant assumptions. Before the model can yield psychologically meaningful statements, a number of assumptions must be incorporated from hypotheses derived from existing theories and research in CRT tasks.

Assumptions for RSM:

Assumption 1: The probability of entering the response selection state is independent of the stimulus. It is assumed that entry to the response selection state is determined prior to or at the initiation of a trial and is therefore stimulus independent. Perhaps, entry to the response selection state may be determined by the events of the previous trial (e.g. an error occurred or the subject responded too slow). Formally then, $P_{ik} = P_k$, for all S_i.

Assumption 2: The bias probabilities of the guessing state are independent of the stimulus. It is intended by a guessing process that no stimulus information is utilized in the selection of a response. Therefore, the guessing probability is taken to be independent of the stimulus. Formally, this is represented by: $b_{jik} = b_{ik}$, for all S_j.

<u>Assumption 3</u>: The latency distributions of the guessing state are independent of the stimulus. The rationale used in Assumption 2 is applied to Assumption 3. Formally, $G_{jik} = G_{ik}$ and therefore $V_{jik} = V_{ik}$, for all S_j.

<u>Assumption 4</u>: The latency distributions of the SCR state are independent of the stimulus. It was argued earlier that the research of Falmagne (1965), Kornblum (1969), Bertelson (1965) and Bertelson and Renkin (1966) indicates that response mechanisms are largely responsible for the variations in CRT as a function of set size. To determine whether these results can be generalized to the present experiments, it is assumed that the latency distributions of the SCR state are independent of the stimulus but are dependent upon the response. Formally, $L_{jik} = L_{ik}$ and therefore $\mu_{jik} = \mu_{ik}$, for all S_j.

<u>Assumption 5</u>: The latency distributions of the SCR state are independent of the time deadline. This is equivalent to the invariance assumption of Link and Tindall (1970, 1971), Ollman (1966) and Yellott (1967, 1971). The research of Ollman (1966) and Yellott (1967, 1971) in standard CRT tasks supported this assumption but the research of Link and Tindall (1970, 1971) in modified CRT and discrimination tasks rejected the invariance assumption. In an attempt to generalize the results of Ollman (1966) and Yellott (1967, 1971), the invariance hypothesis will be assumed for the n-choice RSM. Formally, this is: $\mu_{ik} = \mu_i$, for all time deadlines k.

<u>Assumption 6</u>: The latency distributions of the SCR state are independent of the stimulus set size. In order to test the hypothesis, proposed by Crossman (1955), that the relationship between CRT and stimulus set

size is due to a decrease in discriminability, the assumption of independence of the SCR latency distributions from stimulus set size is adopted. The experiments by Link and Tindall (1970, 1971) revealed that within time deadlines, the latency distributions were invariant across changes in stimulus similarity. It was inferred therefore, that if stimulus similarity were the variable which produced the set size - CRT relationship then the latency distributions of the SCR state should also remain invariant across changes in set size.

If assumptions 1 - 5 are imposed on the general RSM, then the following simplifications in the equations for Pc_i, Pe_{ji}, Mc_i and Me_{ji} result:

$$Pc_i = P_k\, a_{iik} + (1 - P_k)\, b_{ik} \qquad (1)$$

$$Pe_{ji} = P_k\, a_{jik} + (1 - P_k)\, b_{ik}, \text{ for } i \neq j \qquad (2)$$

$$Mc_i = (P_k\, a_{iik}\, \mu_i + (1 - P_k)\, b_{ik}\, V_{ik})/Pc_i \qquad (3)$$

$$Me_{ji} = (P_k\, a_{jik}\, \mu_i + (1 - P_k)\, b_{ik}\, V_{ik})/Pe_{ji}, \text{ for } i \neq j \qquad (4)$$

If equation (2) is subtracted from equation (1) then we obtain:

$$Pc_i - Pe_{ji} = P_k\, (a_{iik} - a_{jik}) > 0, \text{ for all } i \neq j \qquad (5)$$

and

$$Pc_i Mc_i - Pe_{ji}\, Me_{ji} = P_k\, (a_{iik} - a_{jik})\, \mu_i, \text{ for all } i \neq j \qquad (6)$$

If we divide equation (6) by equation (5), we obtain an estimate of the mean latency of response i from the response selection state.

$$\mu_i = (Pc_i Mc_i - Pe_{ji} Me_{ji})/(Pc_i - Pe_{ji}) \qquad (7)$$

Therefore, Assumptions 1 - 6, when imposed upon the general RSM, result in the predictions that the mean, μ_i, of the latency distributions of the SCR state calculated according to equation (7) are invariant across changes in the stimulus for a given response, across time deadlines and across stimulus set size.

Simplified Response Selection Model (SRSM)

If we make an additional assumption, then the RSM is greatly simplified to the SRSM.

Assumption 7: The probability of the selection of a correct response from the response selection state is unity. The argument for this assumption is one of parsimony. Initially, it does not seem economical to a assume that the subject will make confusions in the selection of a response. Therefore, $a_{iik} = 1$, for all S_i and deadlines k.

Equations (1) - (7) become:

$$Pc_i = P_k + (1 - P_k)\, b_{ik} \qquad (1')$$

$$Pe_{ji} = (1 - P_k)\, b_{ik}, \text{ for all } i \neq j \qquad (2')$$

$$Mc_i = (P_k\, \mu_i + (1 - P_k)\, b_{ik}\, V_{ik})/Pc_i \qquad (3')$$

$$Me_{ji} = ((1 - P_k)\ b_{ik}\ V_{ik})/Pe_{ji} = V_{ik}, \text{ for all } i \neq j \tag{4'}$$

$$Pc_i - Pe_{ji} = P_k > 0, \text{ for all } i \neq j \tag{5'}$$

$$Pc_i Mc_i - Pe_{ji} Me_{ji} = P_k\ \mu_i, \text{ for all } i \neq j \tag{6'}$$

$$\mu_i = (Pc_i Mc_i - Pe_{ji} Me_{ji})/(Pc_i - Pe_{ji}), \text{ for all } i \neq j \tag{7'}$$

Therefore, for stimulus set size n, the data from each time deadline condition will permit us to test the predictions of invariance for n(n - 1) estimates of P_k derived from equation (5') and (n - 1) estimates of b_{ik}, μ_i and V_{ik} derived from equations (2') and (5'), (7') and (4'),respectively. The extent to which these estimates are invariant is a measure of the adequacy of the model.

The following assumptions lead to simplications of the SRSM. Although they are not essential for any of the above relationships, each assumption leads to a testable prediction.

Assumption 8: The bias probabilities of the guessing state are independent of the time deadlines. Initially, we wish to assume that the guessing process is a unitary process which will not be influenced by the time deadline. Formally, $b_{ik} = b_i$, for all time deadlines k.

Assumption 9: The latency distributions of the guessing state are independent of the time deadline. The same argument as was used in Assumption 8 will be used. Formally, $G_{ik} = G_i$ and therefore $V_{ik} = V_i$, for all time deadlines k.

Assumptions 8 and 9 lead to the additional predictions that estimates of b_i and V_i derived from equations (2') and (5') and (4'), respectively, will be invariant across time deadlines.

In order to investigate some additional features of the model, n the number of stimuli and responses will be varied. Of interest will be the relationship between size of the response set and the parameters of the processor-controlled and guessing states. The results of this investigation should provide implications for the types of mechanisms which underlie the response selection process. If the probability parameters vary in such a manner to reflect a conditionalization based upon the set size while the latency distributions of the processor-controlled states remain invariant, a parallel selection processor is implied. However, if response latency increases with set size, it might be concluded that either the discriminability of the alternatives in the response system is reduced or that a sequential process underlies response selection.

The following experiment was designed to test the response selection model presented above and to obtain some information on the nature of the mechanisms underlying the response selection process. Since, the following experiment represents the traditional choice reaction time task and cannot be interpreted as a discrimination task, the tests of the invariance hypothesis will have a direct bearing on the discrepancies between the research of Ollman (1966) and Yellott (1967, 1971) and those of Link and Tindall (1970, 1971). It is hoped that this investigation will point the way to a rapprochement of these results.

In addition, the experiment and analysis, according to the above models, will have implications for the convolution and sequential processing theories. The results will have a direct bearing on the generality of Sternberg's serial search model. The theoretical extension of mixture theories to multiple choice tasks serves to provide a needed (Pachella and Fisher, 1972) framework in which convolution theories can be applied to speeded tasks. Furthermore, if invariance of the SCR latency distributions obtains across stimulus set sizes as it has for stimulus similarity and interstimulus interval, as would be expected by Crossman (1955), the development of sequential processing theories for multiple choice tasks would also have to include mechanisms which could "normalize" the magnitude of stimulus information obtained from different stimulus set sizes. If invariance across stimulus set size does not obtain then sequential processing theories extended to multiple choice tasks will have to produce qualitatively different results from those which must be deduced to account for invariance of SCR latency across stimulus similarity and interstimulus interval.

CHAPTER TWO

Method

Six subjects, paid $2.00/session, were used. Nineteen experimental sessions, excluding practise, were run. Each session was approximately one hour in duration and consisted of three blocks of either 280 or 310 trials/block. The first ten trials of each block were considered to be practice trials and discarded from the analysis.

Six stimuli were used. These stimuli were chosen to be easily recognizable with a minimum of confusions. The six stimuli are shown in Figure 2.

Insert Figure 2

Each stimulus was associated with one of six response buttons. The assignment of stimuli to buttons was arranged in a latin square and each of the six subjects received one assignment. The six response keys were spaced in an arc equidistant from a home key (HK). The buttons were designed to provide an 80 gram resistance to depression. A sketch of the response panel with the buttons numbered for later reference is presented in Figure 3.

Insert Figure 3

Three time deadlines were used: 300, 440 ms and accuracy. The time deadlines were randomized across trials within each experimental session.

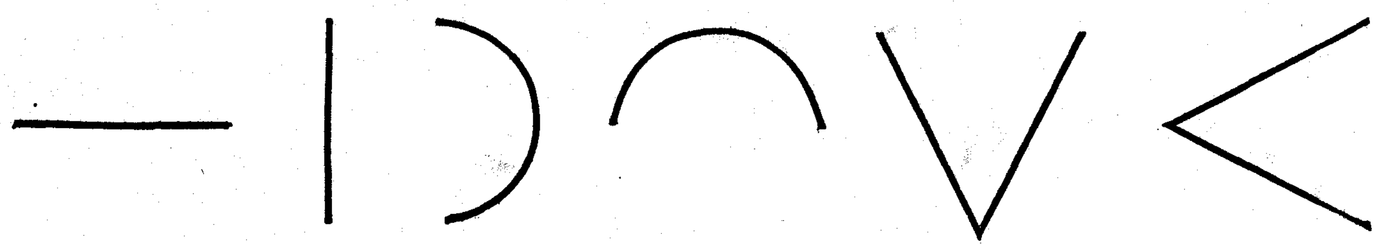

Figure 2. The six visual stimuli.

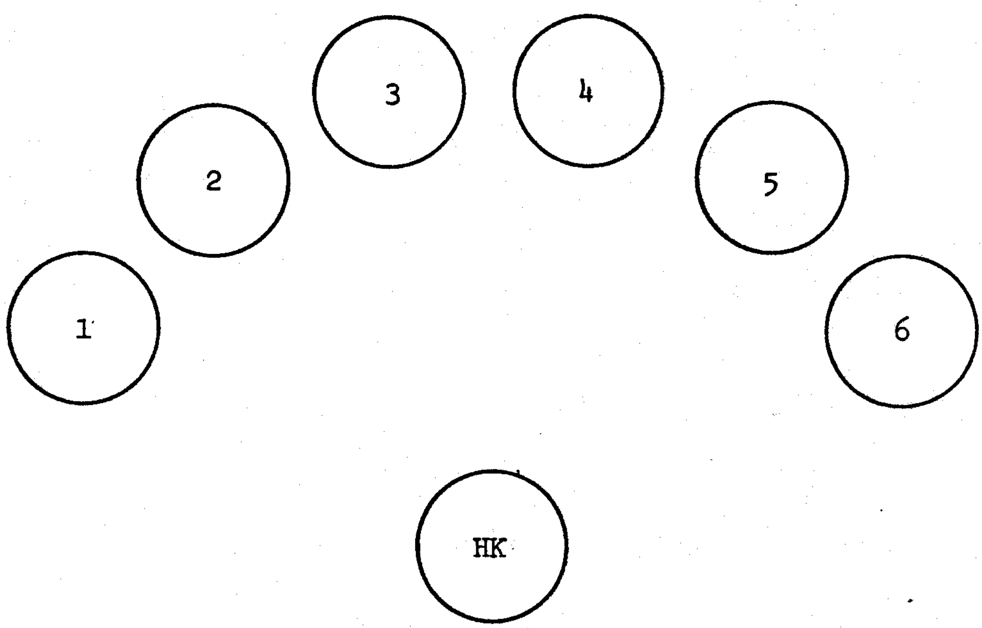

Figure 3. The response panel.

The number of stimuli and responses available to the subject was varied across three levels: 2, 4 and 6 alternatives. For both the 2 and 4 alternative conditions, three sets of responses were chosen and presented to each subject. The purpose of this procedure was to equate the amount of practise a subject got on each response. The sets of response alternatives for the 2 and 4 response conditions are presented in Table 1. The numbers refer to the corresponding buttons on the response panel as shown in Figure 3. For the 2 and 4 response conditions, the response panel was altered by removing the buttons which were not represented in the stimulus set.

Insert Table 1

The number of response alternatives was fixed within an experimental session. For the 2 and 4 response conditions, the three response sets were used within a single session but in separate blocks of 310 trials each. Within each response set, each stimulus was presented equally often. The order of the response sets within a session was randomized across sessions. In an attempt to counterbalance for practise effects across sessions, the following order of sessions was used: 6 4 6 2 6 4 6 4 6 2 6 4 6 4 6 2 6 4 6. The number of sessions for each of the 2, 4 and 6 alternative conditions is explained below.

The total number of stimulus conditions given by number of stimuli per set X number of response sets X time deadlines is 18, 36 and 18 for the 2, 4 and 6 alternative conditions, respectively. It was assumed that 450 replications of each stimulus under each time deadline

Table 1

The sets of response alternatives for the 2 and 4 response conditions.

	Number of Alternatives	
	2	4
Response Configuration	1, 6	1, 2, 5, 6
	2, 5	1, 3, 4, 6
	3, 4	2, 3, 4, 5

would provide quite stable estimates of the response probability and mean latencies. The data from the three response sets within the 2 and 4 response conditions were combined. After the first 10 warmup trials were excluded from each block, the number of trials which were run in the 2, 4 and 6 response conditions was 2700, 5400 and 8100, respectively. These data were collected in 3, 6 and 10 experimental sessions for the 2, 4 and 6 response conditions, respectively. The 2 and 4 response sessions consisted of 3 blocks of 310 trials each.

On each trial, the subject depressed the home key (HK) to initiate the events shown in Figure 4. While HK was depressed a ready signal (the character R) accompanied by information indicating the time deadline in effect on that trial was presented visually on a computer controlled oscilloscope (Tektronix 602 - P4 phosphor) for 700 ms.

Insert Figure 4

The ready signal was followed by one of the stimuli. When the subject recognized the stimulus and selected a response, he released HK and depressed one of the response keys with the finger which was used to depress HK. After the response, the subject was informed via the oscilloscope, when appropriate, whether the response was correct (YES or NO) and whether the time criterion was exceeded (SPEED OK or TOO SLOW). Each feedback display was presented for 500 ms. If the subject released HK before the stimulus was presented, the trial was aborted and restarted with the next depression of HK. Response time was measured from onset of the stimulus until depression of a choice key.

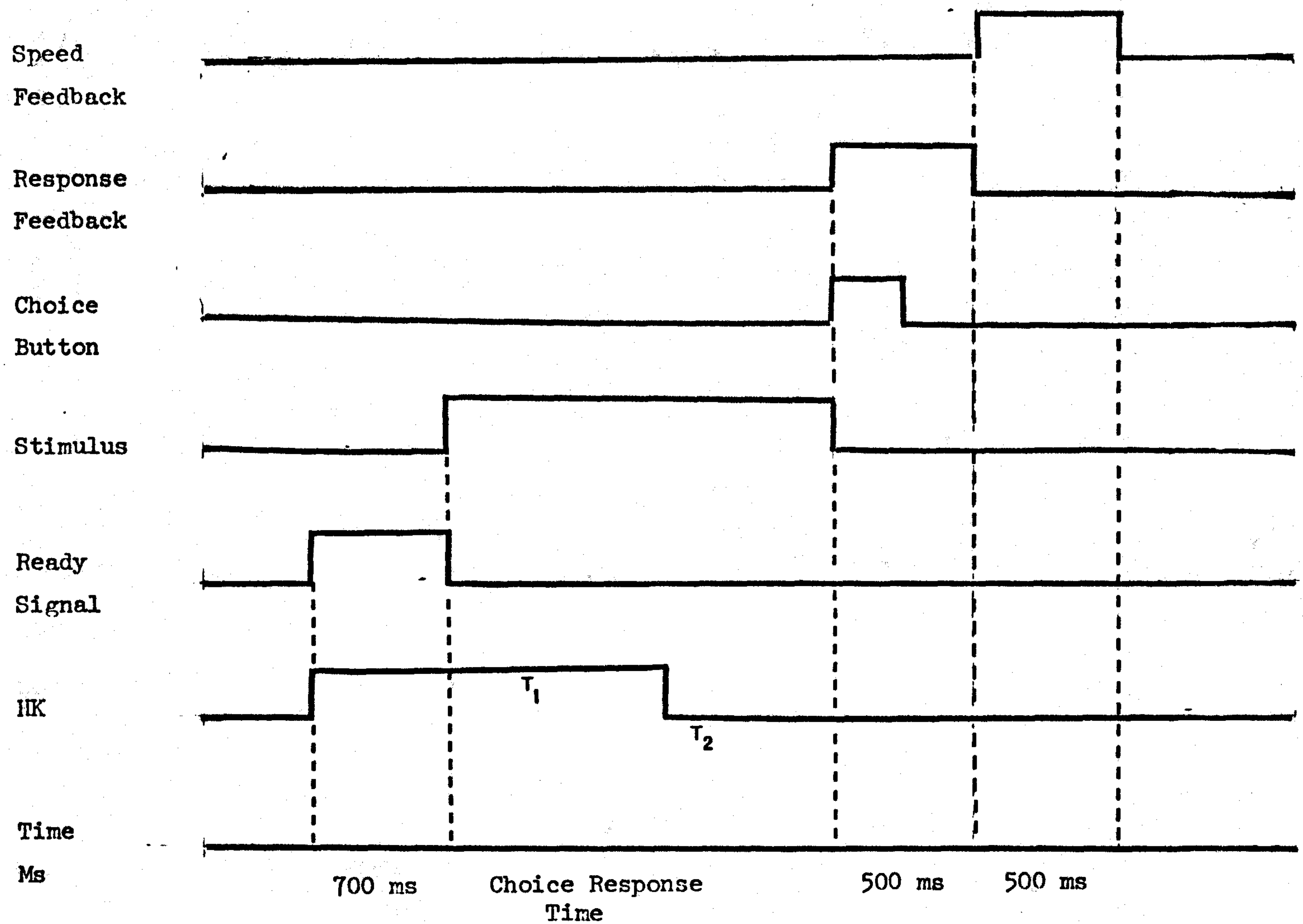

Figure 4. The events of a single trial.

Two components of response time were collected on each trial. The time from the onset of the stimulus until the release of HK and the time from release of HK until depression of a choice button (movement time). Most analyses of response time were performed on the total response time.

The instructions and feedback differ somewhat for the 300, 440 ms and accuracy conditions. In the accuracy condition, subjects received no feedback regarding the speed of their responses and were told to take as long as they required to respond accurately. In the 300 ms condition, subjects received no feedback regarding the accuracy of their responses and were told to respond fast enough to beat the time deadline. In the 440 ms condition, subjects received feedback regarding both accuracy and speed. Subjects were told to respond just fast enough to beat the time deadline and while doing so to be as accurate as possible. In the accuracy and 300 ms conditions, when feedback was omitted, the appropriate feedback display was replaced with a blank display of 500 ms duration in order that the total duration of experimenter-controlled within trial events did not differ across conditions.

All experimental events, measurements of time, recording of responses and presentation of visual displays were controlled by a PDP 8/I computer. The computer laboratory system has been described by Link (1969). Basically, the system consists of a KW8/IF programmable crystal clock, response panel interfacing and a special system for the calligraphic display of visual information.

CHAPTER THREE

Results

The data from 6 subjects who performed in tasks involving three different stimulus set sizes and three different instructional sets for response speed were analyzed. Estimates of response probabilities and response latencies were obtained for the grouped data of the 6 subjects. Corresponding estimates for individual subjects are presented in the appendices. Estimates of probability correct, mean correct and mean error latency averaged over stimuli for each stimulus set size - time deadline condition for all 6 subjects combined were obtained.

Estimates of Response Probabilities

Estimates of response probabilities were obtained for the 6, 4 and 2 stimulus conditions.

For the 6 stimulus condition, excluding warmup trials, each of the 6 stimuli at each of the 3 time deadlines was presented 15 times within a single block of an experimental session (15 trials/stimulus/block X 6 stimuli X 3 time deadlines = 270 analyzed trials/block). Three blocks were run per session for a total of 10 sessions. For each subject, a total of 450 trials were analyzed on each stimulus within a time deadline (15 trials/stimulus/block X 3 blocks/session X 10 sessions = 450 trials/stimulus). The estimates of response probabilities were averaged over the 6 subjects for a total of 2700 trials/stimulus and for the 6-choice condition are presented in Table 2.

Insert Table 2

Table 2

Estimates of the probability of response i given stimulus j for the time deadline conditions: accuracy, 440 and 300 ms combined for all 6 subjects. The estimated probabilities are based on 2700 presentations of each stimulus. The stimulus set size within sessions was 6.

Accuracy

Response

		1	2	3	4	5	6
Stimulus	1	.933	.021	.029	.008	.007	.003
	2	.016	.926	.016	.014	.024	.004
	3	.012	.016	.922	.033	.013	.004
	4	.004	.004	.043	.902	.040	.007
	5	.004	.020	.004	.029	.913	.029
	6	.005	.003	.007	.006	.040	.939

440 Ms

Response

		1	2	3	4	5	6
Stimulus	1	.595	.089	.101	.097	.081	.038
	2	.082	.533	.087	.106	.153	.040
	3	.059	.082	.576	.160	.090	.032
	4	.032	.060	.115	.613	.136	.043
	5	.035	.067	.066	.152	.604	.076
	6	.046	.060	.063	.095	.153	.582

300 Ms

Response

		1	2	3	4	5	6
Stimulus	1	.281	.090	.164	.172	.187	.107
	2	.110	.253	.164	.182	.184	.107
	3	.110	.090	.331	.194	.176	.099
	4	.116	.088	.183	.311	.205	.099
	5	.110	.097	.160	.186	.341	.106
	6	.130	.091	.156	.167	.186	.270

For the 4 stimulus condition, excluding warmup trials, each of the 3 four-stimulus sets in Table 1 was used for one of the three blocks within the 6 four-stimulus sessions. Within a block, each of the 4 stimuli was presented for 25 trials at the 3 time deadlines (25 trials/stimulus/block X 4 stimuli X 3 time deadlines = 300 trials/block.) Each stimulus was presented in 2 of the 3 blocks of a session for a total of 6 sessions. For each subject, a total of 300 trials were run on each stimulus within a time deadline (25 trials/stimulus/block X 2 blocks/session X 6 sessions = 300 trials/stimulus). The estimates of response probabilities were averaged over the 6 subjects for a total of 1800 trials/stimulus. Estimates of response probabilities for the 4-choice condition are presented in Table 3.

Insert Table 3

For the 2 stimulus condition, excluding warmup trials, each of the 3 two-stimulus sets in Table 1 was used during one of the three blocks within the 3 two-stimulus sessions. Within a block, each of the 2 stimuli was presented for 50 trials at the 3 time deadlines (50 trials/stimulus/block X 2 stimuli X 3 time deadlines = 300 trials/block). Each stimulus was presented in one of the three blocks of a session for a total of 3 sessions. For each subject, a total of 150 trials were run on each stimulus within a time deadline (50 trials/stimulus/block X 1 block/session X 3 sessions = 150 trials/stimulus). The estimates of response probabilities were averaged over the 6 subjects for a total of 900 trials/stimulus. Estimates of response probabilities for the

Table 3

Probability of response i given stimulus j for the time deadline conditions: accuracy, 440 and 300 ms, combined for all 6 subjects. The probabilities are based on 1800 presentations of each stimulus. The stimulus set size within sessions was 4.

Accuracy

		Response 1	2	3	4	5	6
Stimulus	1	.956	.007	.016	.005	.007	.010
	2	.018	.912	.022	.010	.035	.004
	3	.003	.010	.938	.040	.004	.005
	4	.003	.006	.023	.939	.022	.008
	5	.005	.017	.008	.035	.917	.020
	6	.007	.005	.003	.016	.024	.946

440 Ms

		Response 1	2	3	4	5	6
Stimulus	1	.687	.056	.066	.066	.069	.057
	2	.052	.578	.082	.087	.172	.030
	3	.035	.045	.666	.185	.045	.025
	4	.023	.026	.138	.708	.064	.041
	5	.035	.107	.060	.102	.645	.053
	6	.078	.046	.041	.083	.076	.676

300 Ms

		Response 1	2	3	4	5	6
Stimulus	1	.413	.081	.092	.111	.108	.195
	2	.108	.338	.098	.126	.243	.088
	3	.092	.076	.365	.260	.112	.096
	4	.090	.088	.198	.411	.122	.091
	5	.103	.171	.111	.128	.396	.092
	6	.203	.105	.100	.112	.104	.377

2-choice condition are presented in Table 4. Estimates of mean response latencies and other theoretical values for the two-choice condition to be discussed later are also presented in Table 4.

Insert Table 4

Similar tables for individuals are presented in the appendices.

Estimates of Mean Response Latencies

Estimates of mean response latencies for individual subjects were obtained in the same manner as was described earlier for the estimates of the corresponding response probabilities. Mean response latencies combined for the 6 subjects for the 6, 4 and 2 stimulus set conditions are presented in Table 5, 6 and 4, respectively. Individual subject tables are presented in the appendices. The response frequency upon which these means are based can be determined from the corresponding response probabilities of Tables 2, 3 and 4, respectively.

To simplify these data, estimates of mean response latency for a given stimulus and also for a given response are also presented in Tables 5 and 6. Finally, estimates of mean error response latency for a given response ($Av.V_i$) are also presented in Tables 5 and 6.

Insert Tables 5 and 6

To further summarize these data, estimates of probability correct, mean correct and mean error response latencies were obtained for each stimulus set size-time deadline condition. Probability correct and mean

Table 4

Estimates of probability correct, Pc_i, probability of error response i given stimulus j, Pe_{ji}, mean correct latency, Mc_i, mean error latency for response i given stimulus j, Me_{ji}, probability of entering the response selection state, P_k, mean latency for response i, μ_i, from the selection state and bias probability, b_i, of response i from the guessing state. These estimates are for average data for all 6 subjects in the 2 stimulus set condition.

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i	b_i
1	6	.975	.020	491	294	.955	496	.444
2	5	.958	.040	471	308	.918	478	.488
3	4	.912	.062	476	295	.850	489	.413
4	3	.938	.088	431	309	.850	444	.587
5	2	.960	.042	451	320	.918	457	.512
6	1	.980	.026	464	265	.955	469	.578

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i	b_i
1	6	.806	.135	433	249	.671	469	.410
2	5	.819	.120	418	276	.699	443	.399
3	4	.740	.157	380	258	.583	412	.376
4	3	.843	.260	356	260	.583	398	.624
5	2	.880	.181	368	265	.699	395	.601
6	1	.866	.195	388	264	.671	424	.593

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i	b_i
1	6	.593	.345	340	206	.249	526	.459
2	5	.637	.348	330	207	.289	478	.489
3	4	.575	.353	322	217	.221	489	.453
4	3	.647	.426	311	213	.221	500	.547
5	2	.652	.363	302	204	.289	425	.511
6	1	.656	.407	315	202	.249	501	.542

Table 5

Mean response latency (ms) combined for all 6 subjects in the 6-choice condition.

Accuracy

Response

		1	2	3	4	5	6	Av.
Stimulus	1	612	441	492	381	245	267	600
	2	509	646	446	332	414	296	629
	3	330	598	636	525	287	318	623
	4	295	397	489	625	420	359	606
	5	261	488	319	395	617	495	601
	6	424	333	276	356	420	644	629
	Av.	603	636	619	607	590	634	
	Av. V_i	401	553	461	430	395	427	

440 Ms

Response

		1	2	3	4	5	6	Av.
Stimulus	1	512	332	316	258	264	269	422
	2	373	528	299	272	333	270	428
	3	319	325	521	327	282	270	432
	4	253	298	312	475	330	282	410
	5	271	296	277	313	479	341	410
	6	294	297	246	256	339	510	420
	Av.	453	441	424	384	398	449	
	Av. V_i	317	312	295	292	317	296	

300 Ms

Response

		1	2	3	4	5	6	Av.
Stimulus	1	504	234	197	199	198	203	288
	2	231	539	213	199	200	204	292
	3	218	242	422	213	199	202	282
	4	207	248	245	447	215	204	293
	5	216	216	196	198	423	233	282
	6	210	220	198	192	217	569	304
	Av.	310	341	271	264	264	333	
	Av. V_i	216	232	211	201	206	209	

Table 6.

Mean response latencies (ms) combined for all 6 subjects in the 4-choice stimulus condition.

Accuracy

		Response 1	2	3	4	5	6	Av.
Stimulus	1	593	378	424	343	346	384	584
	2	498	637	495	364	394	333	619
	3	466	530	605	427	253	333	594
	4	360	343	440	576	454	359	567
	5	316	417	357	489	610	460	597
	6	356	323	227	356	470	583	573
	Av.	587	627	593	561	593	574	
	Av. V_i	433	418	436	428	418	402	

440 Ms

		Response 1	2	3	4	5	6	Av.
Stimulus	1	509	326	304	267	259	262	438
	2	347	512	312	279	300	270	423
	3	348	299	482	290	242	263	418
	4	278	265	298	443	317	281	400
	5	289	274	261	316	467	328	405
	6	270	281	244	285	291	499	427
	Av.	459	439	412	378	396	449	
	Av. V_i	304	289	291	289	288	284	

300 Ms

		Response 1	2	3	4	5	6	Av.
Stimulus	1	443	200	213	206	203	189	300
	2	219	443	242	199	210	188	289
	3	218	219	411	215	192	204	283
	4	204	229	220	388	220	208	287
	5	212	221	207	209	407	207	290
	6	217	211	202	200	215	461	305
	Av.	308	306	290	272	281	303	
	Av. V_i	215	217	217	208	245	198	

correct response latencies were obtained from Tables 2 - 6 for each time deadline by averaging across stimuli. Mean error response latencies were obtained from Tables 2 - 6 by averaging across stimuli and responses for all stimulus $i \neq$ response j. These averaged response probabilities and latencies are presented in Table 7. The first entry in each cell represents probability correct, the second mean correct latency and the third mean error latency. Probability correct for the 6, 4 and 2 stimulus set conditions is based upon 16,200, 10,800 and 5,400 observations, respectively.

Insert Table 7

Table 7

Mean estimates of probability correct, mean correct response latency and mean error response latency combined for all 6 subjects and all stimuli within a stimulus set size - time deadline condition.

			Time Deadline	
Stimulus Set Size		Accuracy	440 ms	300 ms
6	Pc	.923	.584	.298
	Mc	630	503	478
	Me	434	304	210
4	Pc	.935	.660	.383
	Mc	600	485	425
	Me	428	290	210
2	Pc	.954	.826	.627
	Mc	464	390	319
	Me	304	263	209

CHAPTER FOUR

Tests of the Mixture Theories

The Simple Response Selection Model (SRSM) because it requires the additional strong assumption that discriminability in the response selection state is perfect (no confusion in the response buffer, i.e. $a_{iik} = 1$), leads to a number of predictions in addition to the invariance prediction of the RSM. The SRSM predicts that (1) error probability Pe_{ji} will remain invariant, within time deadlines, for a given R_i across S_j (equation 2'), (2) the probability of entering the response selection state, P_k, for time deadline k will be invariant across stimulus and response alternatives (equation 5'), (3) the probability of R_i from the guessing state, b_i, will be independent of S_j (equations 2' and 5') and the time deadline k (Assumption 8), (4) mean error latency for R_i is independent of S_j (equation 4') and the time deadline k (Assumption 9). Both the SRSM and the RSM predict that mean latency of R_i from the response selection state, μ_i, will be invariant across stimuli and time deadlines (equation 7) and stimulus set size (Assumption 6).

While it is possible, as will soon be apparent, to reject the SRSM with a number of these predictions, it was decided to examine each prediction in detail so that the particular way in which the SRSM failed would suggest more satisfactory alternative models.

Tests of the SRSM

Invariance of Error Probability

From equation (2'), response probability i is equal to the probability of entering the guessing state times the probability of guessing response i. Response probability is independent of the stimulus j, for all $j \neq i$. The statement that response probability is simply a product of two factors can be tested for the 6 and 4 choice stimulus conditions. Estimates of response probability for the 6 and 4 stimulus conditions were presented in Tables 2 and 3, respectively.

Within each column of the matrices in Tables 2 and 3, the off-diagonal probabilities should be invariant. Rather then simply test for invariance of the off-diagonal probabilities, a more complete analysis of the error probabilities will be performed. This analysis will determine whether error probabilities can be expressed as a multiplication of two factors. For the SRSM, the factors are the response factor, b_i, and the entry state probability, $1 - P_k$.

Falmagne (1972) has presented the necessary conditions for testing a model similar to the SRSM by analysis of the error matrices. The SRSM satisfies the conditions of what Falmagne refers to as biscalability.

Briefly, these conditions are:

(1) let u and v be real valued functions defined on the response set, R, and the stimulus set, S, respectively.

(2) let $K \subset R \times S$ be the set of all (a,x) such that response a is an incorrect response to stimulus x.

(3) then error probability is assumed to a real valued function, F, defined for all pairs of numbers of the form (u(a),v(x)) with $(a,x) \epsilon K$ and is assumed to be strictly monotonic in both arguments.

$$Pe(a,x) = F(u(a),v(x))$$

In addition, error probability for the SRSM (equation (2')) satisfies the condition that:

$$Pe(a,x) = u(a) \cdot v(x)$$

which Falmagne denotes as multiplicative. For the SRSM, v(x) is a constant, $1 - P_k$, for a given time deadline and u(a) is equal to b_i where i refers to response a and is constant across S_j. Falmagne states that the multiplicative condition can be regarded as a generalization of the quasi-independence condition of Goodman (1968) and that therefore Goodman's procedure for determining independence of row and column factors in data matrices with missing or deleted cells can be applied to test equation (2').

According to Goodman (1968), a confusion matrix with missing or deleted cells is defined as quasi-independent if

$P_{ij} = P_{i.} \cdot P_{.j}$, for all i and j over the nondeleted cells of the matrix. Where $P_{i.}$ and $P_{.j}$ are the marginal proportions in row i and column j defined on the nondeleted cells of the confusion matrix and P_{ij} is the proportion in cell (i,j).

To test the multiplicative condition and thereby test equation (2') of the SRSM with regard to the error matrix, Goodman's test for quasi-independence was performed on the error matrices of Tables 2 and 3 for each time deadline. Goodman's iterative procedure produces estimates of b_i and $(1 - P_k)$ and these are used to estimate the proportion of errors which should occur in each cell of the error matrices of Tables 2 and 3. The predicted values of b_i and $1 - P_k$ along with the estimated and actual error frequencies are presented in the appendices.

The usual chi-square goodness of fit tests were run to compare observed and expected frequencies. The values of chi-square for each of the matrices of Tables 2 and 3 are presented in Table 8.

The computed chi-square (d.f. = 19) values for all but the 6 stimulus condition at 300 ms are significant at well beyond the .005 level.

Insert Table 8

Thus the assumption of multiplicativity for error probability (equation (2')) of the SRSM must be rejected. While this general test rejects equation (2') as a suitable representation of error probability, Goodman (1968) does not suggest a method which could be used to determine whether the failure was due to changes in b_i across stimuli, $1 - P_k$ across responses, or whether some additional process must be included in the error probabilities. Invariance of P_k and b_i are investigated below.

It should also be noted in Tables 2 and 3, that there is a slight tendency for the estimates of Pe_{ji} to increase near the diagonal cells within a column. These trends are consistent with equation (2) of the RSM under assumptions which will be presented below when invariance of b_i is tested.

Probability of Entering the Response Selection State

From equation (5'), it is predicted that for a stimulus set size of n, the estimates of the probability, P_k, of entering the response selection state which can be obtained for each time deadline will be invariant. Although not predicted by the model, the estimates of P_k will also be tested for independence of stimulus set size. Estimates of P_k were obtained from the matrices of Tables 2 and 3, by subtracting off-diagonal entries of a column from the diagonal entry, for a given

Table 8

Computed values of chi-square with 19 degrees of freedom for the goodness of fit tests of observed to predicted frequencies calculated for Tables 2 and 3, according to the assumption of quasi-independence.

	Time Deadline		
Stimulus Set Size	Accuracy	440 Ms	300 Ms
6	506	407	27
4	219	647	871

response. These estimates of P_k are presented for the 6 stimulus condition in Table 9 and for the 4 stimulus condition in Table 10. The 30 estimates of P_k within each matrix of Tables 9 and 10 should be invariant. Estimates of P_k for stimulus set size 2 can be obtained from Table 4.

Insert Tables 9 and 10

These estimates were obtained according to equation (5') from estimates of probability correct and error probabilities also presented in Table 4. The response probabilities in Table 4 are rather less stable than those of Tables 2 and 3 since each stimulus in the 2-stimulus set condition was only presented 150 times/subject. The estimated probabilities are therefore based upon 900 presentations of each stimulus.

Six estimates of P_k for each time deadline are presented in Table 4. Individual subject tables corresponding to Tables 9, 10 and 4 are presented in the appendices.

In order to test for the invariance of P_k in Tables 9,10 and14, it was necessary to obtain estimates of the variance of P_k. From equation (5')

$$\hat{P}_k = \hat{P}c_i - \hat{P}e_{ji} \tag{5'}$$

the variance of P_k was assumed to be given by

$$\text{Var}\ (\hat{P}_k) = \text{Var}\ (\hat{P}c_i) + \text{Var}\ (\hat{P}e_{ji}) \tag{8}$$

Table 9

Estimates of P_k obtained by subtracting the off-diagonal column entries from the diagonal column entry in Table 2. The stimulus set size was 6.

Accuracy

Response

		1	2	3	4	5	6
Stimulus	1	----	.905	.894	.894	.906	.936
	2	.917	----	.906	.888	.889	.935
	3	.922	.910	----	.868	.899	.936
	4	.929	.921	.879	----	.873	.933
	5	.929	.905	.918	.873	----	.910
	6	.928	.922	.916	.896	.873	----
	Av.	.925	.913	.902	.884	.888	.930

440 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.444	.475	.516	.523	.545
	2	.513	----	.489	.507	.452	.542
	3	.536	.452	----	.453	.514	.550
	4	.563	.473	.462	----	.468	.540
	5	.560	.466	.510	.462	----	.506
	6	.549	.473	.513	.518	.451	----
	Av.	.544	.461	.490	.491	.482	.536

300 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.163	.167	.139	.154	.163
	2	.171	----	.167	.129	.157	.163
	3	.171	.162	----	.117	.165	.171
	4	.165	.165	.148	----	.137	.172
	5	.171	.156	.171	.125	----	.164
	6	.151	.162	.175	.144	.155	----
	Av.	.166	.162	.165	.131	.154	.167

Table 10

Estimates of P_k obtained by subtracting the off-diagonal column entries from the diagonal column entry in Table 3. The stimulus set size was 4.

Accuracy

Response

Stimulus	1	2	3	4	5	6
1	----	.905	.922	.935	.910	.937
2	.938	----	.916	.930	.882	.942
3	.953	.902	----	.899	.913	.941
4	.953	.906	.915	----	.895	.938
5	.952	.895	.930	.904	----	.927
6	.949	.907	.935	.923	.893	----
Av.	.949	.903	.927	.918	.898	.937

440 Ms

Response

Stimulus	1	2	3	4	5	6
1	----	.522	.600	.643	.576	.619
2	.635	----	.584	.622	.473	.647
3	.652	.533	----	.524	.600	.651
4	.664	.552	.528	----	.581	.635
5	.652	.471	.607	.607	----	.623
6	.609	.532	.625	.625	.569	----
Av.	.642	.522	.589	.604	.560	.635

300 Ms

Response

Stimulus	1	2	3	4	5	6
1	----	.258	.273	.300	.288	.182
2	.306	----	.267	.286	.153	.289
3	.322	.263	----	.151	.285	.281
4	.323	.251	.167	----	.275	.286
5	.311	.168	.255	.283	----	.285
6	.211	.233	.266	.299	.292	----
Av.	.294	.235	.246	.264	.259	.264

where $\text{Var}(\hat{Pc}_i) = \hat{Pc}_i(1 - \hat{Pc}_i)/n$

and $\text{Var}(\hat{Pe}_{ji}) = \hat{Pe}_{ji}(1 - \hat{Pe}_{ji})/n$

where n represents the number of times a stimulus was presented. For equation (8) to be correct, one must assume that Pc_i and Pe_{ji} are independent or that the correlation between them is zero. In the event that Pc_i and Pe_{ji} are correlated, the estimate of Var (P_k) from equation (8) will be too large and will result in a overly-conservative test of the invariance of P_k. Inspite of this reservation regarding the estimates of Var (P_k), it was considered informative to present estimates of P_k as calculated from equation (5'). However, failure to reject invariance of P_k must be interpreted with caution.

In order to obtain stable estimates of Var (P_k), estimates of Var (P_k) were obtained for each response within a time deadline, for each subject. These estimates of Var (P_k), within time deadlines, were averaged over responses and subjects. To avoid the obvious violation of independence which would occur if equation (8) were summed over stimuli and responses, an average estimate of the probability of an error involving response i, $\hat{Pe}_{.i}$, was obtained for each response i.

$$\hat{Pe}_{.i} = 1/(n-1) \sum_{j=1}^{n} \hat{Pe}_{ji} \text{ , for } j \neq i$$

This average estimate, $\hat{Pe}_{.i}$, was used in equation (8) to obtain an estimate of Var (P_k) for each response i within a time deadline.

$$\mathrm{Var}\ (\hat{P}_k) = \mathrm{Var}\ (\hat{Pc}_i) + \mathrm{Var}\ (\hat{Pe}_{.i})$$

where $\mathrm{Var}\ (\hat{Pe}_{.i}) = \hat{Pe}_{.i}\ (1 - \hat{Pe}_{.i})/n.$

The estimates of Var (P_k) were averaged across responses within a time deadline and stimulus set size. Average estimates for the standard deviation of P_k, SD (P_k), for each time deadline and stimulus set size were obtained by taking the square root of the average of estimates of Var (P_k). These average estimates of SD (P_k) are presented in Table 11 along with average estimates of P_k obtained from Tables 9, 10 and 4 by averaging the values of P_k across stimulus j for all j $\neq$ i and across response i.

Of the estimates of P_k within Tables 9, 10 and 4, 68/90, 77/90 and 16/18, respectively deviate from the means of P_k presented in Table 11, for a fixed time deadline-stimulus set size condition by more than two standard deviations. Thus the hypothesis of invariance of P_k across stimulus-response pairs can be rejected.

Insert Table 11

While SRSM did not predict invariance of P_k across changes in stimulus set size, it was considered informative to determine the nature of any trends which might exist in P_k across set size. The average estimates of P_k are presented in Table 11.

Average estimates of SD (P_k) were obtained for each time deadline by averaging the variances across stimulus set sizes and taking

Table 11

Average estimates of P_k obtained from Tables 9 and 10 by averaging the values of P_k across stimulus j for all $j \neq i$ and across response i. Estimates of the standard deviation of P_k were calculated as described in the text. Average estimates and standard deviations of P_k were obtained for stimulus set sizes: 6, 4 and 2 and across the time deadline conditions: accuracy, 440 and 300 ms. P_k is the upper number in each cell of the table.

Stimulus Set Size		Accuracy	440 Ms	300 Ms
6	P_k	.907	.501	.158
	$SD(P_k)$	.0023	.0043	.0043
4	P_k	.922	.592	.260
	$SD(P_k)$	.0026	.0050	.0054
2	P_k	.908	.651	.253
	$SD(P_k)$	.0040	.0070	.0091
Av. P_k		.912	.581	.224
Av. $SD(P_k)$		.0030	.0054	.0063
S.E. (P_k) for Set Sizes: 4 & 6		.0005	.0010	.0012
S.E. (P_k) for Set Size: 2		.0012	.0022	.0026

the square root of these average variances. Average SD (P_k)s are presented in Table 11. In order to test whether the average P_k within time deadlines changes as a function of set size, it was necessary to obtain an estimate of the standard error of the mean of P_k. For stimulus set sizes 4 and 6, the average Var (P_k) was divided by 30, since 30 estimates of P_k went into the calculation of the mean of P_k. For stimulus set size 2, Var (P_k) was divided by 6.

Estimates of the standard error of P_k, S.E., are presented in Table 11. All three of the mean estimates of P_k across stimulus set size deviate from the overall mean of P_k for each time deadline by much more than two standard deviations. That is, all nine of the estimates of mean P_k for a given set size deviate from their respective mean values of P_k for each time deadline. Therefore, P_k seems to be dependent upon the stimulus set size.

Invariance of P_k was rejected. It should be noted in Tables 9 and 10 that there is a tendency for P_k within columns to decrease near the diagonal cells. These trends in P_k are consistent with equation (5) of the RSM under the conditions that $a_{iik} \neq 1$ and that specific trends in a_{jik} to be described in the next section exist.

<u>Guessing Probabilities</u>

The SRSM predicts that estimates of the probability of response i from the guessing state, b_i, should be independent of the stimulus j and the time deadline k. If the estimate of P_k obtained from equation (5') is used in equation (2') estimates of b_i may be obtained. The corresponding estimates of P_k from Tables 9, 10 and 4 were used according to equation (2') to obtain estimates of b_i from Tables 2, 3 and 4, respectively, Estimates of b_i for the 6, 4 and 2 stimulus conditions are presented in Tables 12, 13 and 4, respectively.

Insert Tables 12 and 13

Because no ready estimate of the variance of b_i was available, it was not possible to statistically test the invariance of b_i. However, examination of Tables 12, 13 and 4 indicate that the b_i within columns vary considerably. This variability is particularly pronounced in the accuracy condition and somewhat less so in the 440 ms condition. Since the estimates of b_i vary by as much as .319 in the accuracy condition and .213 in the 440 ms condition, it is unlikely that invariance of b_i can be accepted. It should be pointed out, however, that these examples of large variability in b_i occur in time deadline conditions in which the estimates of Pe_{ji} are rather small and unstable. Also, since the estimate of $1 - P_k$ tends to be small for these time deadlines, the apparent variation in Pe_{ji} would be magnified.

However, an additional observation also suggests rejection of the invariance of b_i. In the accuracy and 440 ms conditions, there is a tendency for estimates of b_i to decrease away from the diagonal cells. That is, as the stimulus to which response i was made becomes more remote from stimulus i, the estimate of b_i decreases. In Figures 5 and 6, estimates of b_i are plotted as a function of the distance from the diagonal cells in Tables 12 and 13, respectively. The diagonal position in Figures 5 and 6 is indicated by the D on the abscissa.

To clarify the meaning of the plots in Figures 5 and 6, consider in Figure 5, the points joined by line A. From left to right, the

Table 12

Estimates of probability of response i from the guessing state, t_i, calculated from Tables 2 and 9 according to equations (2') and (5').

Accuracy

Response

		1	2	3	4	5	6
Stimulus	1	----	.221	.274	.076	.075	.047
	2	.193	----	.170	.125	.216	.062
	3	.154	.178	----	.250	.129	.063
	4	.056	.051	.355	----	.315	.105
	5	.056	.211	.049	.228	----	.322
	6	.070	.039	.083	.058	.315	----

440 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.160	.192	.200	.170	.084
	2	.168	----	.170	.215	.279	.087
	3	.127	.150	----	.293	.185	.071
	4	.073	.114	.214	----	.256	.094
	5	.080	.126	.135	.283	----	.154
	6	.102	.114	.129	.197	.279	----

300 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.108	.197	.200	.221	.128
	2	.133	----	.197	.209	.218	.128
	3	.133	.107	----	.220	.210	.119
	4	.139	.105	.215	----	.238	.120
	5	.133	.115	.193	.213	----	.108
	6	.153	.109	.189	.195	.220	----

Table 13

Estimates of probability of response i from the guessing state, b_i, calculated from Tables 3 and 10 according to equations (2') and (5').

Accuracy

		Response					
		1	2	3	4	5	6
Stimulus	1	----	.074	.205	.077	.078	.159
	2	.290	----	.262	.143	.297	.069
	3	.064	.102	----	.396	.046	.085
	4	.064	.064	.271	----	.210	.129
	5	.104	.162	.114	.365	----	.274
	6	.137	.054	.046	.208	.224	----

440 Ms

		Response					
		1	2	3	4	5	6
Stimulus	1	----	.117	.165	.185	.163	.150
	2	.143	----	.197	.230	.326	.085
	3	.101	.096	----	.389	.113	.072
	4	.069	.058	.292	----	.153	.112
	5	.101	.202	.153	.260	----	.141
	6	.200	.098	.109	.221	.176	----

300 Ms

		Response					
		1	2	3	4	5	6
Stimulus	1	----	.109	.127	.159	.152	.238
	2	.156	----	.134	.177	.287	.124
	3	.136	.103	----	.306	.157	.134
	4	.133	.118	.238	----	.168	.128
	5	.150	.206	.149	.179	----	.129
	6	.257	.137	.136	.160	.147	----

points refer to estimates of b_i for response 1 when stimuli 6, 5, ..., 2, respectively, were presented. According to the invariance hypothesis, the points joined by line A should lie along a line parallel to the abscissa. However, as can be seen by tracing line A, as the stimulus approaches the diagonal, estimates of b_i increase.

Consider, also, the points joined by line A'. These points from left to right refer to estimates of b_i for response 6 when stimuli 5, 4, 3, 2 and 1, respectively, were presented. Symmetric responses such as responses 1 and 6 are coded with the same form of line (solid line for response 1 and 6).

Insert Figure 5

For an additional example, consider the points joined by line B. These points from left to right refer to estimates of b_i for response 2 when stimuli 6, 5, 4, 3 and 1, respectively, were presented. The point for stimulus 1 is indicated by the open circle to the right of the diagonal. A similar line (dashed line) symmetric to line B occurs to the right of the diagonal for response 5 with a corresponding open square for stimulus 6, to the left of the diagonal. Line C corresponds to response 3 and the three points to the left of the diagonal refer to the presentation of stimuli 6, 5 and 4 while the two points (open circles with dotted line) to the right of the diagonal refer to stimuli 2 and 1, respectively. A symmetric line for response 4 occurs to the right of the diagonal and has two points (open squares with dotted line) to the left of the diagonal.

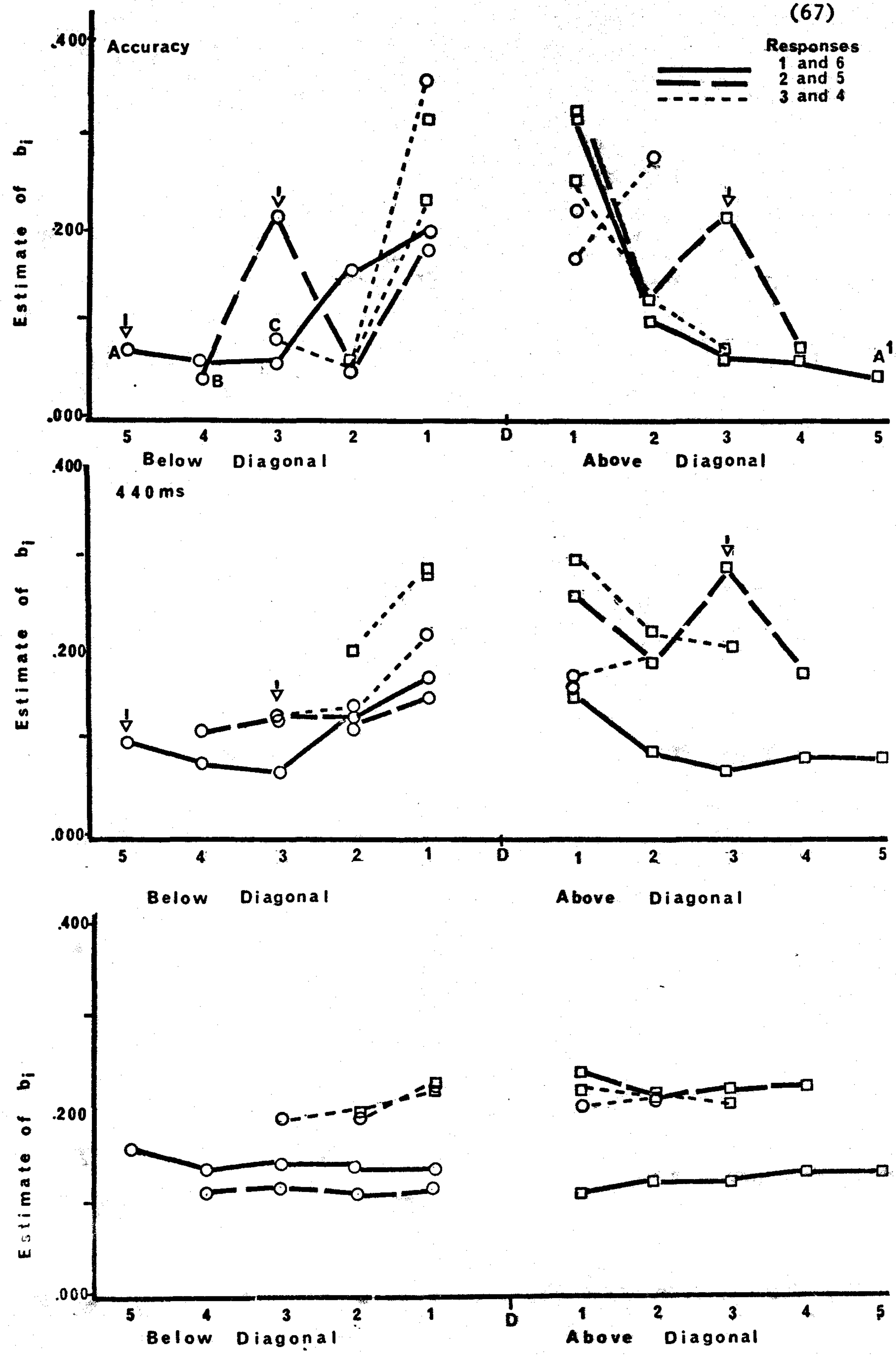

Figure 5. Estimates of b_i as a function of distance from the diagonal.

The trends in b_i would not be accounted for by increased variation in the estimates of Pe_{ji} and $1 - P_k$, but suggest perhaps, some additional process which is not represented in the SRSM.

Insert Figure 6

These observations suggest that there might have been some confusion in the response buffer (i.e. $a_{iik} \neq 1$). Welford (1968) has presented a review of the research and some information theory models (e.g. Fitts, 1954; Crossman, 1957) which attempt to account for relationships between the speed and accuracy of motor movements. While no theoretical development of the scatter of motor movements will be attempted here, it is noted that the tradeoff relationships between spatial scattering of motor movements and movement time is well-established (Welford, 1968). A simple hypothesis for the present situation might be that confusion between responses increases as a function of proximity on the response panel. From the RSM, which permits confusion in the response buffer, equations (2) and (5) can be substituted for equations (2') and (5') of the SRSM which were used to estimate b_i then

$$Pe_{ji}/(1 - (Pc_i - Pe_{ji})) = \frac{P_k a_{ji} + (1 - P_k)\, b_i}{1 - P_k\, (a_{ii} - a_{ji})} \qquad (9)$$

Furthermore, for fixed P_k and b_i, according to assumptions 1 and 2 of RSM, if a_{ji} were to increase as j approached i then the observed trends in b_i, estimated according to the SRSM, would be predicted.

If we accept the indication above that the trends in b_i, estimated according to the SRSM, across changes in stimulus j are due to changes in

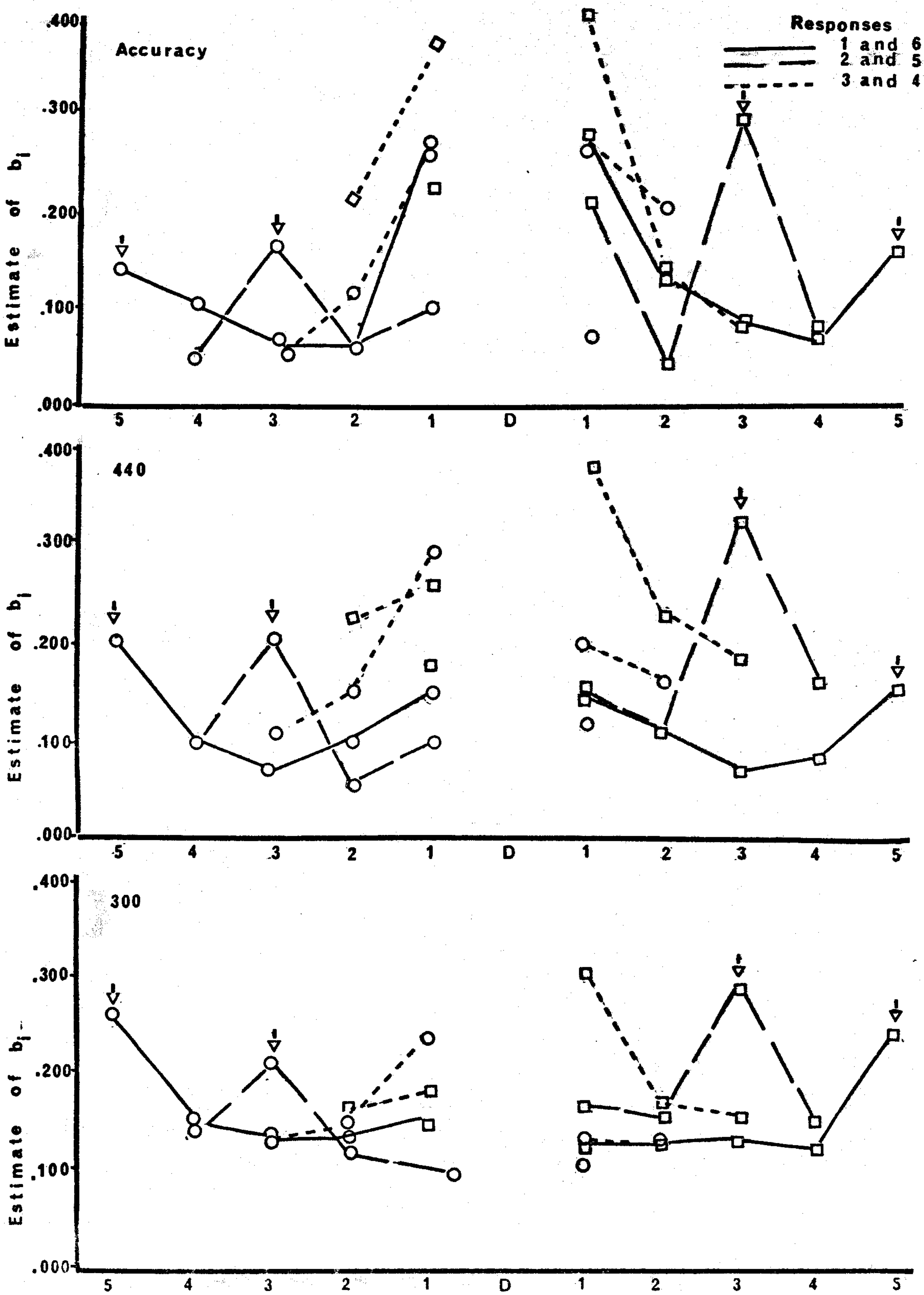

Figure 6. Estimates of b_i as a function of distance from the diagonal.

a_{ji}, then according to equation (9), if P_k were reduced by more stringent time deadlines any effects due to changes in a_{ji} would be decreased and the trends in b_i estimated from equations (2') and (5') would be reduced. In fact, as P_k approaches zero, the calculation in equation (9) will approach an estimate of b_i for the RSM. It can be seen in Figures 5 and 6 that the curves for the estimates of b_i, calculated according to the SRSM did begin to flatten out in the 300 ms condition, in which P_k was low (Table 11).

It is not possible to make too strong an argument regarding the trends in the estimates of b_i in Tables 12 and 13 and Figures 5 and 6 because the trends are not sufficiently consistent. One possible explanation for the inconsistency in the trends of b_i might be the result of an unforeseen relationship between buttons on the response panel. It is possible that buttons symmetrical with regard to the subjects' left and right sides might have had a tendency to be confused. If this were the case, the particular pairing in the 2 stimulus and, perhaps the 4 stimulus condition might have enhanced this confusion. This enhanced confusion might occur because, in the 2 stimulus condition, the only error which can occur must be to the symmetrical button on the opposite side of the panel (see Table 1 for stimulus sets). A similar but less exaggerated reduction in possible error alternatives occurs in the 4 stimulus condition. Examination of Figures 5 and 6 indicates that the violations in the monotonic trends away from the diagonals, involve pairs of stimuli with symmetric responses. Those violations which might be due to symmetry are indicated in Figures 5 and 6 by small arrows above them.

Mean Error Latency

Equation (4') predicts that mean error latency for response i will be independent of the stimulus j, for all $j \neq i$ and assumption 9 states that it will be independent of the time deadline k for the SRSM. Estimates of mean response latencies for individual subjects were obtained in the same manner as was described earlier for the estimates of the corresponding response probabilities. Mean response latencies combined for the 6 subjects for the 6, 4 and 2 stimulus set conditions are presented in Tables 5, 6 and 4, respectively.

Within each column of the matrices in Tables 5 and 6, the off-diagonal mean latencies should be invariant. The variation within a column for the accuracy condition is of the order of 200 ms between the longest and shortest mean error latency for a given response i. Variation within columns for the 440 ms condition is somewhat less and is of the order of 80 - 100 ms. The mean error latencies for the 300 ms condition are relatively invariant. Consequently, the assumption of invariance in mean error latencies within a column must be rejected.

Also, it should be observed that there is a tendency for the mean error latencies to be longer near the diagonal and to become shorter when the stimulus is further from the diagonal.

In Figure 7, estimates of V_i are plotted as a function of the distance from the diagonal cells in Table 5. The meaning of the points associated with each curve are identical to those of Figures 5 and 6 except that error latency, V_i, is substituted for guessing probability, b_i. A similar figure could have been obtained for the values of V_i from Table 6 for the 4 stimulus condition. These trends in the estimates of V_i cannot be accounted for by the SRSM.

Insert Figure 7

If we adopt the RSM and make the intuitively reasonable assumption that the average response latency associated with the response selection state is longer than that associated with the guessing states and that a_{ji} increases as j approaches i (confusion in the response buffer) then equation (4) would predict the systematic increases in error latencies as j approaches i:

$$Me_{ji} = (P_k \, a_{ji} \, \mu_{ji} + (1 - P_k) \, b_i \, V_i)/Pe_{ji} \qquad (4)$$

It is also encouraging to note that the violations in monotonicity of error latencies moving away from the diagonal, occur on the symmetric stimuli as was observed in the case of the estimates of b_i in Figure 5. In fact, except for scale factors the general shapes of the curves in Figures 5 and 7 are very similar. This similarity in the shapes of the curves would also be predicted from equations (2) and (4) of the RSM.

It was also predicted that mean error latency for response i would be independent of the time deadline. To facilitate this comparison, the overall mean error latencies for each response were obtained by averaging across stimuli in Tables 5 and 6. The average V_is are plotted in Figure 8 across time deadline conditions. The average decrease in V_i in going from the accuracy condition to the 440 ms condition is 140 ms and the average decrease in V_i from the 440 ms to the 300 ms condition is 92 ms. The average change in V_i from the Accuracy condition to the 300 ms

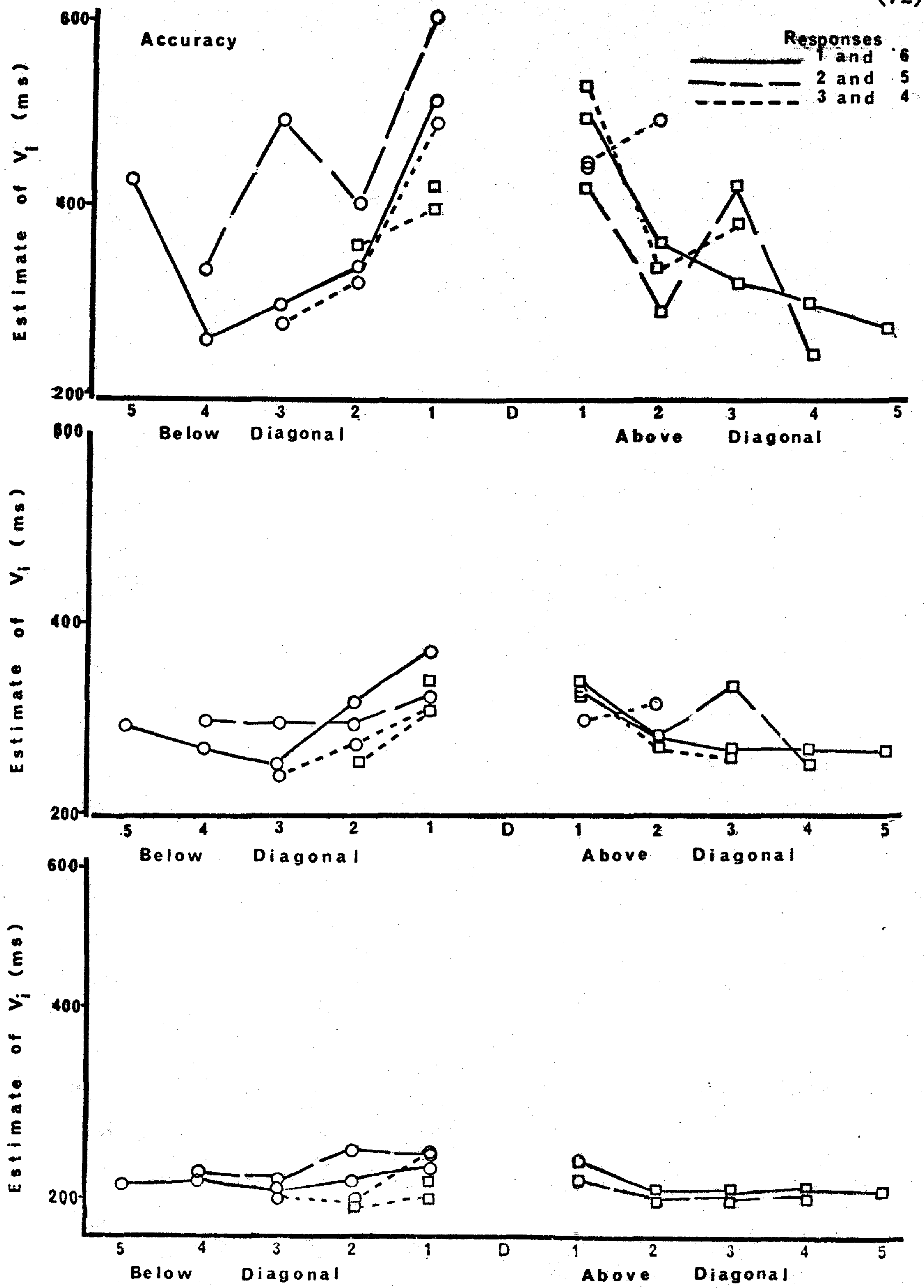

Figure 7. Estimates of V_i as a function of distance from the diagonal in Table 5. For the 6 stimulus set condition.

condition is therefore 232 ms, which suggests rejection of the invariance of mean error latency across time deadlines.

Insert Figure 8

In summary, the SRSM must be rejected. The four predictions which were examined were found not to hold.

The test for quasi-independence on the error probabilities indicates that error probability cannot be accounted for by any simple multiplicative function of $1 - P_k$ and b_i such as the one represented in equation (2').

The test for invariance of response bias from the guessing state indicated that response bias varied as a function of the stimulus. There was an indication that b_i decreased away from the diagonal cells. It was suggested that this observation might indicate that there was some confusion in the response buffer (i.e. $a_{ii} \neq 1$). A simple hypothesis that confusion between responses increased as a function of proximity on the response panel was proposed and examined. The trends in b_i and the flattening out of the trends at shorter time deadlines are consistent with the RSM.

The test for invariance of mean error response latency indicated that error latencies decreased as a function of time deadlines and also, as with the estimates of b_i, the error latencies tended to decrease away from the diagonal cells. Both trends in mean error latencies can be accounted for by equation (4) of the RSM. If the mean latency of the response selection state is longer than the mean latency of the guessing state, then as P_k approaches 0, mean error latency will approach

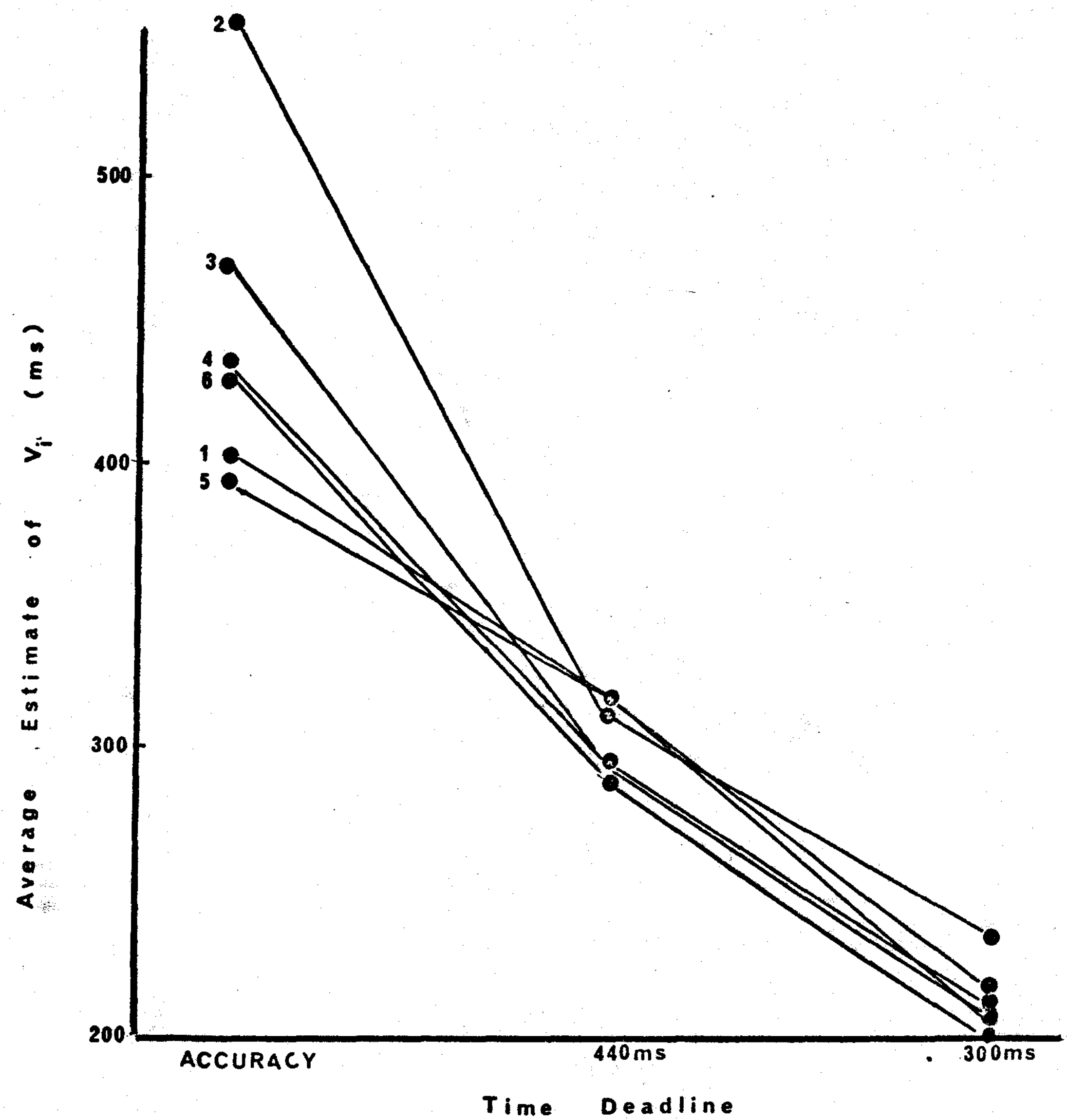

Figure 8. Average estimates of V_i from Table 5 for the three time deadline conditions. The numbers to the left of each line refer to the response associated with each V_i.

the mean of the guessing state. Also, as j approaches i, a_{ji} will in- ~~crease and~~ error latencies will include a larger proportion of longer selection state latencies.

The quasi-independence test on the error probabilities could have failed because b_i was not constant across stimuli. However, the trends in P_k, b_i and V_i suggest a more specific interpretation. A model such as the RSM which permits confusion in the response buffer would account for these trends. Also, equation (2) of the RSM for error probability indicates that the quasi-independence test failed because errors consist of an additional component which represents the SCR process.

Tests of the RSM

On the basis of these results, it would seem that the RSM is a viable alternative to the SRSM. It accounts for the above results, at least at a qualitative level. The RSM, however, does lead to one readily testable quantitative prediction. From equation (7), estimates of μ_i, the mean latency of response i from the response selection state, should be invariant across stimuli, time deadlines and stimulus set size.

Estimates of μ_i were calculated from the mean response latencies of Tables 5, 6 and 4 and the response probabilities of Tables 2, 3 and 4 for the stimulus set sizes 6, 4 and 2, respectively. The estimates of μ_i calculated according to equation (7) are presented in Tables 14, 15 and 4 for stimulus set sizes 6, 4 and 2, respectively. Individual subject tables are presented in the appendices.

Invariance of μ_i Across Stimuli:

To test for the invariance of μ_i across stimuli, within time deadlines and stimulus set sizes, average estimates of μ_i were calculated by averaging the estimates of μ_i obtained for each S_j across stimuli. Average μ_i are presented in Tables 14 and 15.

It is not possible to test for invariance of μ_i across stimuli in the 2 stimulus condition as only 1 estimate of μ_i is obtainable.

Insert Tables 14 and 15

Average deviations for μ_i were obtained for the 6 and 4 stimulus conditions for each time deadline. Average deviations for each μ_i were obtained from Tables 14 and 15 by averaging the absolute differences between the 5 estimates of μ_i and the average of these 5 estimates. An overall average deviation for each time deadline-stimulus set size condition was obtained by averaging the deviations across stimuli. The average deviations for the 6 stimulus set are 1.5, 4.5 and 18.5 ms for the accuracy, 440 and 300 ms conditions, respectively and for the 4 stimulus set are 1.0, 9.0 and 62.2 ms for the accuracy, 440 and 300 ms conditions, respectively. The average deviations are relatively small in all conditions but the 4 stimulus condition at the 300 ms time deadline. It might be argued that the estimates of Pc_i, which are used to calculate μ_i, at the shorter deadlines are less stable than at the longer deadlines. This would produce the increases in average deviation.

Except, perhaps, for the 4 stimulus - 300 ms condition, invariance of μ_i is confirmed across stimuli, within time deadlines and stimulus set sizes.

<u>Invariance of μ_i Across Stimulus Set Size:</u>

To test for the invariance of μ_i across set sizes, within time

Table 14

Estimates of μ_i calculated from the mean response latencies of Table 5 and the response probabilities of Table 2 according to equation (7). The stimulus set size was 6.

Accuracy

		Response 1	2	3	4	5	6
Stimulus	1	---	651	641	627	620	646
	2	614	---	640	630	622	646
	3	616	647	---	629	622	646
	4	613	647	644	---	626	647
	5	614	650	638	632	---	649
	6	613	647	639	627	626	---
	Av.	614	648	640	629	623	647

440 Ms

		Response 1	2	3	4	5	6
Stimulus	1	---	567	565	515	512	526
	2	534	---	561	517	528	527
	3	533	565	---	527	514	524
	4	526	558	573	---	522	527
	5	526	562	553	527	---	535
	6	530	557	555	514	527	---
	Av.	530	562	561	520	521	528

300 Ms

		Response 1	2	3	4	5	6
Stimulus	1	---	706	643	751	697	809
	2	679	---	627	797	683	810
	3	687	704	---	833	662	783
	4	711	694	642	---	734	779
	5	688	739	634	819	---	787
	6	757	717	623	742	669	---
	Av.	705	712	634	789	689	794

Table 15

Estimates of μ_i calculated from the mean response latencies of Table 6 and the response probabilities of Table 3 according to equation (7). The stimulus set size was 4.

Accuracy

Stimulus	Response 1	2	3	4	5	6
1	---	639	608	577	612	585
2	595	---	608	578	619	584
3	593	638	---	583	612	584
4	594	639	609	---	614	585
5	594	641	607	579	---	585
6	595	639	606	580	614	---
Av.	594	639	608	579	614	585

440 Ms

Stimulus	Response 1	2	3	4	5	6
1	---	531	502	461	492	521
2	522	---	506	466	528	510
3	517	530	---	498	484	508
4	517	523	530	---	484	514
5	520	565	504	465	---	514
6	539	532	498	465	491	---
Av.	523	536	508	471	496	513

300 Ms

Stimulus	Response 1	2	3	4	5	6
1	---	518	477	455	484	751
2	521	---	472	470	720	543
3	506	507	---	684	492	548
4	509	400	637	---	490	541
5	519	668	499	468	---	542
6	660	547	489	458	476	---
Av.	543	528	515	507	532	585

deadlines, the average estimates of μ_i from Tables 14 and 15, and the single estimates of μ_i from Table 4 were compared. These average estimates of μ_i are presented in Table 16. Within each time deadline and for each response, the estimates of μ_i were compared across set sizes 6, 4 and 2. The assumption of invariance was tested against the alternative that μ_i would decrease with smaller set sizes. Three pairwise comparisons of rank order were made for each response within a deadline, to yield 18 tests/deadline or 54 tests in all. In all 54 tests of rank order the estimates of μ_i decreased with smaller set size. Therefore, the assumption of invariance of μ_i across stimulus set size was rejected.

Insert Table 16

To illustrate the changes in μ_i across stimulus set size, the average estimates of μ_i in Table 16 were averaged across response i for each stimulus set size and time deadline. These average μs are plotted as a function of stimulus set size for each time deadline in Figure 9.

Insert Figure 9

<u>Invariance of μ_i Across Time Deadlines:</u>

Since stimulus set size was a major determinant of the magnitude of μ_i, it was decided to test for the invariance of μ_i across time deadlines for each of the set sizes. The average estimates of μ_i from Table 16 were used to test for invariance of μ_i.

Table 16

Average estimates of μ_i obtained from Tables 14 and 15 by averaging the values of μ_i across stimulus j for all $j \neq i$. Average estimates of μ_i were obtained for stimulus set sizes: 6, 4 and 2 and across the time deadline conditions: accuracy, 440 and 300 ms.

Accuracy

Stimulus Set Size	Response 1	2	3	4	5	6	Average
6	614	648	640	629	623	647	634
4	594	639	608	579	614	585	603
2	496	478	489	444	457	469	472

440 Ms

Stimulus Set Size	Response 1	2	3	4	5	6	Average
6	530	562	561	520	521	528	537
4	523	536	508	471	496	513	508
2	469	443	412	398	395	424	424

300 Ms

Stimulus Set Size	Response 1	2	3	4	5	6	Average
6	705	712	634	789	689	794	721
4	543	528	515	507	532	585	535
2	526	478	489	500	425	501	487

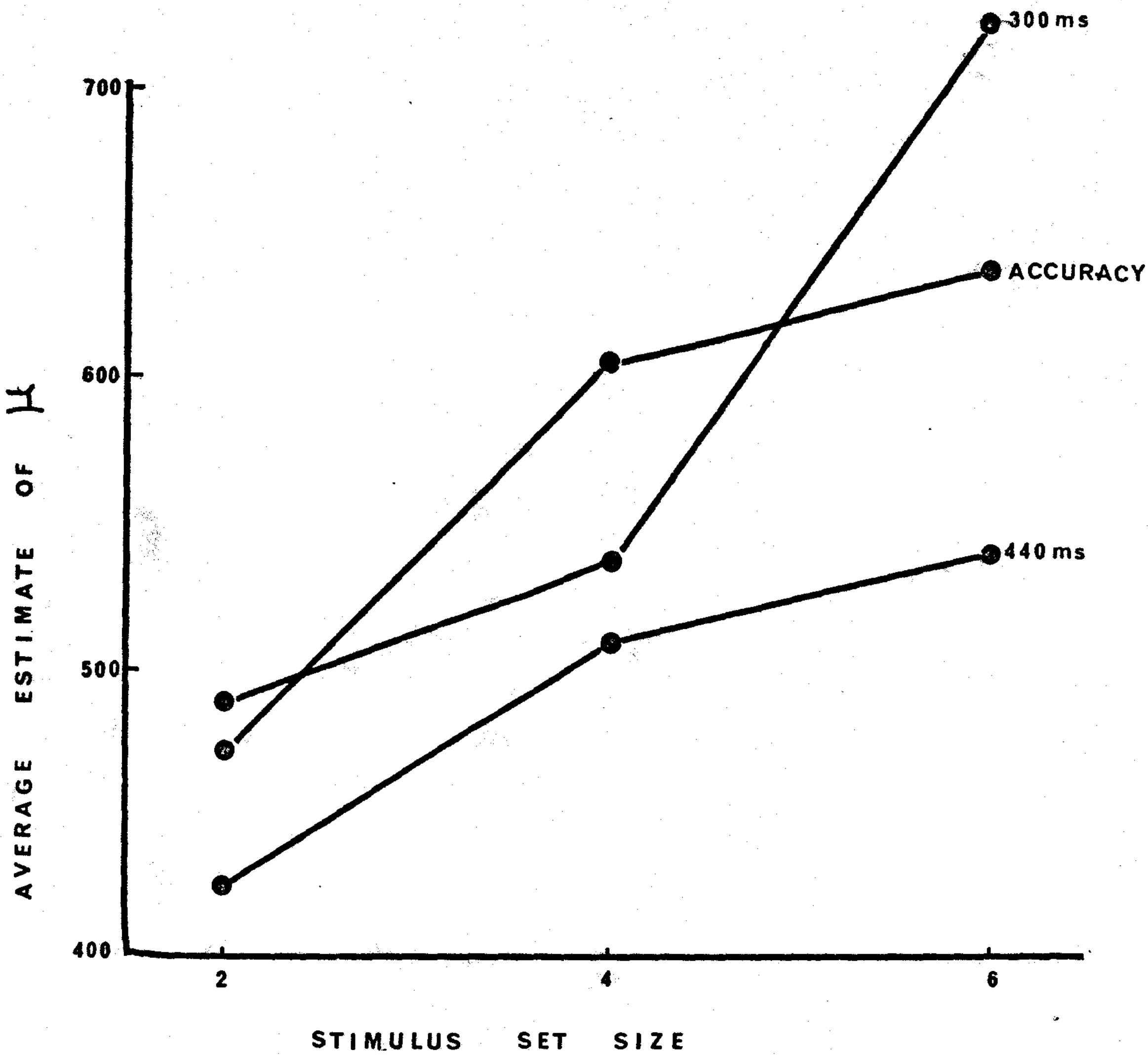

Figure 9. Average estimates of μ, obtained from Table 16 by averaging μ_i across response i for each stimulus set size and time deadline.

The tests for invariance across time deadlines were done in three parts (1) accuracy was compared with 440 ms, (2) 440 ms was compared with 300 ms and (3) accuracy was compared with 300 ms. In all 3 cases a rank order test was used.

(1) Accuracy compared with 440 ms

For each of the 6 responses at each of the set sizes, the estimate of μ_i for the accuracy condition was compared with that of the 440 ms condition. Of the 18 comparisons, in all 18 cases the estimates of μ_i for accuracy were longer than were those for 440 ms.

(2) 440 ms compared with 300 ms

For the 18 comparisons between μ_i for the 440 ms and μ_i for the 300 ms condition, in 17 cases estimates of μ_i for the 300 ms condition were longer than were those for 440 ms.

(3) Accuracy compared with 300 ms

For the 18 comparisons between μ_i for accuracy and μ_i for 300 ms, in 7 cases accuracy was longer than 300 ms, 8 cases 300 ms was longer than accuracy and in 3 cases the μ_i were approximately equal.

The above comparisons can be seen in Figure 9. The accuracy and 300 ms conditions are well above the 440 ms for each set size condition. There appears to be no consistent difference between the accuracy and 300 ms condition when examined across stimulus set size because the 300 ms condition is well above the accuracy condition for set size 6 but well below it for set size 4. There is no obvious explanation for this reversal across stimulus set sizes.

The invariance of μ_i across time deadlines must be rejected since μ_i for the 440 ms condition was found to be shorter than μ_i for the accuracy and 300 ms conditions. However, estimates of μ_i for the accuracy and 300 ms conditions did not differ.

One aspect of the failure of invariance of μ_i is very disturbing in the present experiments. The failure to obtain invariance of μ_i across time deadlines is consistent with many of the previous experiments (Link and Tindall, 1970, 1971; Ollman, 1970) and is not consistent with some others (Ollman, 1966; Yellott, 1967, 1971). However, in all of the previous experiments of Link and Tindall (1970, 1971) the estimates of μ_i tended to order themselves according to the time deadline in force. The estimates of μ_i obtained when the time deadlines were long were larger than estimates of μ_i obtained when the time deadlines were short.

The relationship between estimates of μ_i for the accuracy and 440 ms conditions are consistent with the earlier experiments of Link and Tindall (1970, 1971). But the very large estimates of μ_i for the 300 ms condition are puzzling. As was noted above in Figure 9, the estimates of μ_i for the 300 ms condition were larger than those of the 440 ms condition and, in fact, within the 6 stimulus set condition they were larger than those for the accuracy condition.

Investigation of Large Estimates of μ in 300 ms Condition

The Missed Button Hypothesis

One possible explanation for this result might be that with the greater number of responses and transitory stimulus sets in this experiment, the resulting increased response confusion could have caused subjects to completely miss all response buttons on some trials. If the subject on a 300 ms trial were attempting to respond quickly, he might not take sufficient time to co-ordinate the execution of his response. On such trials, he may then make motor errors and over or undershoot the button to which he was responding. If the subject were to completely miss all the buttons, he might since he would have already exceeded the time deadline reselect the correct response (if the intended response is recognized as an error).

Rabbitt (1966) and Rabbitt and Phillips (1967) have studied the problem of correction of errors in serial CRT tasks. Most errors were found to be responses adjacent to the correct response button (Rabbitt, 1966) with which the results of the present research are consistent. Burns (1965) also found that errors were not entirely random but were generally made to response buttons neighbouring the correct response button. The errors were on the average, detected and corrected in less time than a corresponding accurate response even though no feedback had been presented (Rabbitt, 1966; Rabbitt and Phillips, 1967). However, in some studies, correction of errors take considerably longer than a corresponding accurate response (e.g. Adams and Chambers, 1962). Welford (1968) discusses both results in relation to the concept of a single-channel operation in tracking tasks. He regards the results of Rabbitt (1966) and Rabbitt and Phillips (1967) as indicating that an error has been made by the central effector mechanism rather than the decision mechanism. In terms of the present model (RSM), the correct response may have been selected but the wrong execution occurred. Welford (1968) suggests that visual feedback is not necessary since the feedback from the central effector to the decision mechanism will result in detection of the error and subsequent correction. The results which demonstrate long correction responses (Adams and Chambers, 1962), are interpreted by Welford (1968) as indicating complete reprocessing of the stimulus and perhaps a review of performance strategy. In terms of the RSM, the subject could be assumed to return to the response selection state to reselect the correct response.

This response strategy of reselection of a response would cause some correct responses at the 300 ms time deadline to have very long response times. The long correct response times would lead to disproportionately large estimates of μ_i. If one assumes that the chance of responding in such a way as to completely miss all buttons would increase with the number of buttons then the estimates of μ_i for the 6 stimulus condition at 300 ms would be very large. This argument receives some support from the curves in Figure 9. This result obtains for all 6 subjects, individually, and is not a result of averaging across subjects.

To further investigate the missed button interpretation of the large estimates of μ_i at 300 ms, two types of analyses were undertaken. One analysis was made upon the bivariate distributions of button release time (T1) and movement time (T2) and the other analysis was made upon the T1 response times according to RSM. The analysis of the bivariate distributions offers information regarding the missed button hypothesis since only the movement time could include the missed button component. An analysis of the T1 response times would indicate whether the estimates of μ obtained without a movement time component are different in general form across conditions from the estimates of μ obtained for T1 + T2.

To examine the bivariate response times, bivariate frequency distributions were obtained for all subjects combined. The response time of each trial was decomposed into its two components and these components were used to generate bivariate frequency distributions.

The time to release HK (T1) was analyzed in 50 ms intervals from 0 to 700 ms while the time from release of HK to depression of a choice button (T2) was analyzed in 25 ms intervals from 0 to 700 ms. Bivariate distributions were obtained for correct and error responses for each time deadline and stimulus set size.

The distributions for movement time (T2) were similar for the three time deadlines and stimulus set sizes. The modes for all conditions were between 75-100 ms. It would be expected that if missed buttons had occurred on a significant proportion of the correct response trials that a second mode would be present in the movement time distributions. There was no evidence of bimodality in the T2 distributions. The similarity of the movement time distributions across conditions also argues against the missed button hypothesis. Finally, subjects' reports indicated that though buttons were missed a few times, they did not occur on a substantial proportion of the trials. It is unlikely that missed buttons occurred often but a modification in the experiment would reduce the chances that missed buttons could contribute noise to the data. The response panel could be altered so that the subject could keep his fingers on the alternate response buttons.

Although it is unlikely that missed buttons contributed to the peculiar estimates of μ_i, it is possible that something unaccounted for in the model occurred in the T2 times. To examine this possibility, estimates of T1 and T2 were obtained. Summary estimates of T1 and T2 were obtained by averaging across stimuli, responses and subjects as was done for T1 + T2 in Table 7. Estimates of mean correct and error response latencies for T1 and T2 are presented in Table 17.

The estimates of mean T1 times decrease with time deadline and stimulus set size for both correct and error responses as was observed for T1 + T2 times in Table 7. Only the estimates of mean error times for the 300 ms deadline violate the trend of decreased times with smaller set sizes.

Insert Table 17

There are no consistent trends in the estimates of mean correct T2 times across time deadlines. Mean correct T2 times are smaller for set size 2 than they are for sizes 4 and 6. Mean error T2 times decrease with shorter time deadlines and smaller set sizes. The uniformity of the correct T2 times across time deadlines suggests that some minimum time is required for correct responding and that speed and accuracy cannot be traded off in T2 times.

Constant correct T2 times would tend to inflate the estimates of μ for T1 + T2 times at shorter time deadlines. This can be seen if we modify equation (3) of RSM to include a constant component for T2. Then mean correct latency consists of a component which is a mixture of fast guesses and SCR responses and a fixed component for movement time:

$$Mc_i = (P_k \, a_{iik} \, \mu_i + (1 - P_k) \, b_i \, V_i)/Pc_i + T2^*$$

Then equation (7) becomes:

$$\frac{Pc_i \, Mc_i - Pe_{ji} \, Me_{ji}}{Pc_i - Pe_{ji}} = \mu_i + \frac{Pc_i \, T2^*}{Pc_i - Pe_{ji}}$$

Table 17

Mean estimates of probability correct, mean correct and mean error response latency for button release times (T1) and movement times (T2) for all 6 subjects combined and all stimuli within a stimulus set size - time deadline condition.

Stimulus Set Size			Accuracy	440 Ms	300 Ms
6	T1	Pc	.923	.584	.298
		Mc	372	302	224
		Me	277	185	109
	T2	Mc	258	201	254
		Me	157	119	101
4	T1	Pc	.935	.660	.383
		Mc	365	288	207
		Me	276	172	110
	T2	Mc	235	297	218
		Me	152	118	100
2	T1	Pc	.954	.826	.627
		Mc	300	246	175
		Me	181	150	115
	T2	Mc	164	144	144
		Me	123	113	94

For Pc_i equal to 1, the equation yields an estimate of μ_i + T2* while for Pc_i equal to 1/3 and Pe_{ji} equal to 1/6 as they were approximately in the 300 ms condition, the equation yields an estimate of μ_i + 2T2*. The large estimates of μ in the 300 ms condition could reflect the constant minimum movement time.

In order to learn whether the general conclusions of the analysis of μ for the total response times were due to movement time, estimates of μ were obtained from T1 alone in the manner described T1 + T2 in Tables 14 and 15. Estimates of μ_i based upon T1 times are presented in Tables 18 and 19.

Again, it was not possible to test for invariance of μ_i across stimuli for the 2 stimulus condition.

Insert Tables 18 and 19

Average deviations for μ_i were obtained for the 6 and 4 stimulus conditions for each time deadline as was described earlier for T1 + T2. The average deviations for the 6 stimulus set are .57, 1.43 and 8.76 ms for the accuracy, 440 and 300 ms conditions, respectively and for the 4 stimulus set are .53, 5.71 and 26.66 ms for the accuracy, 440 and 300 ms conditions, respectively. The estimates of average deviations are approximately half the magnitude of those obtained for T1 + T2 and lead to the same conclusions. The hypothesis of invariance of μ_i is again confirmed across stimuli, within time deadlines and stimulus set sizes.

Most conclusions concerning estimates of μ_i obtained from T1 are similar to those reached for estimates of μ_i obtained from T1 + T2. Average

Table 18

Estimates of μ_i calculated from the mean response latencies for T1 and the response probabilities of Table 2 according to equation (7). The stimulus set size was 6.

Accuracy

		Response 1	2	3	4	5	6
Stimulus	1	---	373	377	371	379	376
	2	368	---	376	372	380	376
	3	369	371	---	372	380	376
	4	368	372	377	---	381	376
	5	368	373	375	372	---	376
	6	368	372	376	370	381	---
	Av.	369	372	376	371	380	376

440 Msec

		Response 1	2	3	4	5	6
Stimulus	1	---	333	331	315	315	319
	2	314	---	330	314	320	320
	3	317	334	---	318	315	317
	4	313	333	336	---	316	320
	5	313	334	326	317	---	324
	6	316	332	329	314	316	---
	Av.	315	333	330	316	316	320

300 Msec

		Response 1	2	3	4	5	6
Stimulus	1	---	314	293	341	333	346
	2	319	---	290	365	327	349
	3	323	313	---	378	317	335
	4	336	305	304	---	346	336
	5	323	332	290	364	---	333
	6	358	318	283	338	311	---
	Av.	332	316	292	357	327	340

Table 19

Estimates of μ_i calculated from the mean response latencies for T1 and the response probabilities of Table 3 according to equation (7). The stimulus set size was 4.

Accuracy
Response

		1	2	3	4	5	6
	1	---	371	366	355	374	368
	2	364	---	366	356	378	367
	3	363	371	---	358	373	367
Stimulus	4	364	372	368	---	374	367
	5	364	372	366	357	---	367
	6	365	372	366	357	375	---
	Av.	364	372	367	357	375	367

440 Msec
Response

		1	2	3	4	5	6
	1	---	301	300	287	293	316
	2	299	---	302	290	313	309
	3	297	301	---	309	288	308
Stimulus	4	297	298	318	---	286	311
	5	300	322	302	286	---	310
	6	312	302	299	287	291	---
	Av.	301	305	304	292	294	311

300 Msec
Response

		1	2	3	4	5	6
	1	---	238	225	214	239	370
	2	253	---	221	224	352	274
	3	248	230	---	315	246	275
Stimulus	4	248	234	292	---	241	272
	5	252	300	235	221	---	272
	6	319	249	230	219	234	---
	Av.	264	250	241	239	262	292

estimates of μ_i for T1 obtained from Tables 18 and 19 by averaging over stimuli are presented in Table 20. Estimates of μ_i vary across set size, within time deadlines, as before. The trends are less pronounced, particularly for the 300 ms condition. Across time deadlines, the estimates of μ for the accuracy condition are larger than the estimates of μ for the 440 ms condition as before. However, by comparison with estimates of μ obtained from T1 + T2, estimates obtained from T1 for the 300 ms condition were considerably reduced. The general form of the curves for μ based upon T1 + T2 in Figure 9 is maintained for μ based upon T1 as can be seen in Figure 10. The curve for μ in the 300 ms condition has shifted down to lie across the curve for the 440 ms condition.

Insert Table 20

Most of the results in this experiment are qualitatively unchanged when estimates of μ are obtained for the T1 times. Therefore, arguments that movement times due to missed buttons were responsible for the failure of invariance of μ across stimulus set sizes or the observed difference in μ from the accuracy condition to the 440 ms deadline condition can be rejected. The observation that the 440 and 300 ms curves overlap in Figure 10 is consistent with those of Ollman (1966) and Yellott (1967, 1971) in which estimates of μ do not change across time deadlines. The relatively large drop in the 300 ms curve for μ occurs because the estimates of correct response T2 times in Table 17 are large and equal to the corresponding T2 times for the accuracy and 440 ms conditions. One cannot argue that subjects did not make decisions after release of HK and

Table 20

Average estimates of μ_i calculated for T1 times by averaging the values of μ_i across stimulus j for all $j \neq i$. Average estimates of μ_i were obtained for stimulus set sizes: 6, 4 and 2 and across the time deadline conditions: accuracy, 440 and 300 ms.

Accuracy
Response

Stimulus Set Size	1	2	3	4	5	6	Average
6	369	372	376	371	380	376	374
4	364	372	367	357	375	367	367
2	312	308	295	279	308	303	301

440 ms
Response

	1	2	3	4	5	6	Average
6	315	333	330	316	316	320	322
4	301	305	304	292	294	311	301
2	286	279	256	260	269	277	271

300 ms
Response

	1	2	3	4	5	6	Average
6	332	316	292	357	327	340	327
4	264	250	241	239	262	292	258
2	273	256	260	262	249	277	263

and the shift in the 300 ms curve may result, in part, from such decisions. However, the similarity of form of the curves for μ in Figures 9 and 10 and the maintenance of most conclusions from analysis of T1 + T2 to analysis of T1 times argues against an interpretation of the conclusions of this experiment based upon the large T2 times.

Insert Figure 10

Since the missed button hypothesis appears untenable for this experiment, the observation of most error responses to buttons adjacent to the correct button can be viewed as a corroboration of the results of Rabbitt (1966).

In order to obtain a clearer understanding of the reason for the large estimates of μ in the 300 ms condition, the following analyses were performed. These analyses indicate that the large estimates of μ in the 300 ms condition were not due to peculiarities in the T2 times but to some more general mechanisms which influenced how the subject operated on the 300 ms trials when he was correct. The first analysis that was performed was a comparison of the general form of the frequency distributions of T1 + T2. The results of this analysis suggested examination of sequential dependencies to determine whether the time deadline and response correctness on trial n-1 influenced performance on trial n.

<u>The Fast Guess Strategy on 300 ms Trials</u>

For the analysis of the total response times, response latency frequency distributions were generated in 25 ms intervals for each stimulus within each time deadline and stimulus set size. Error response frequency

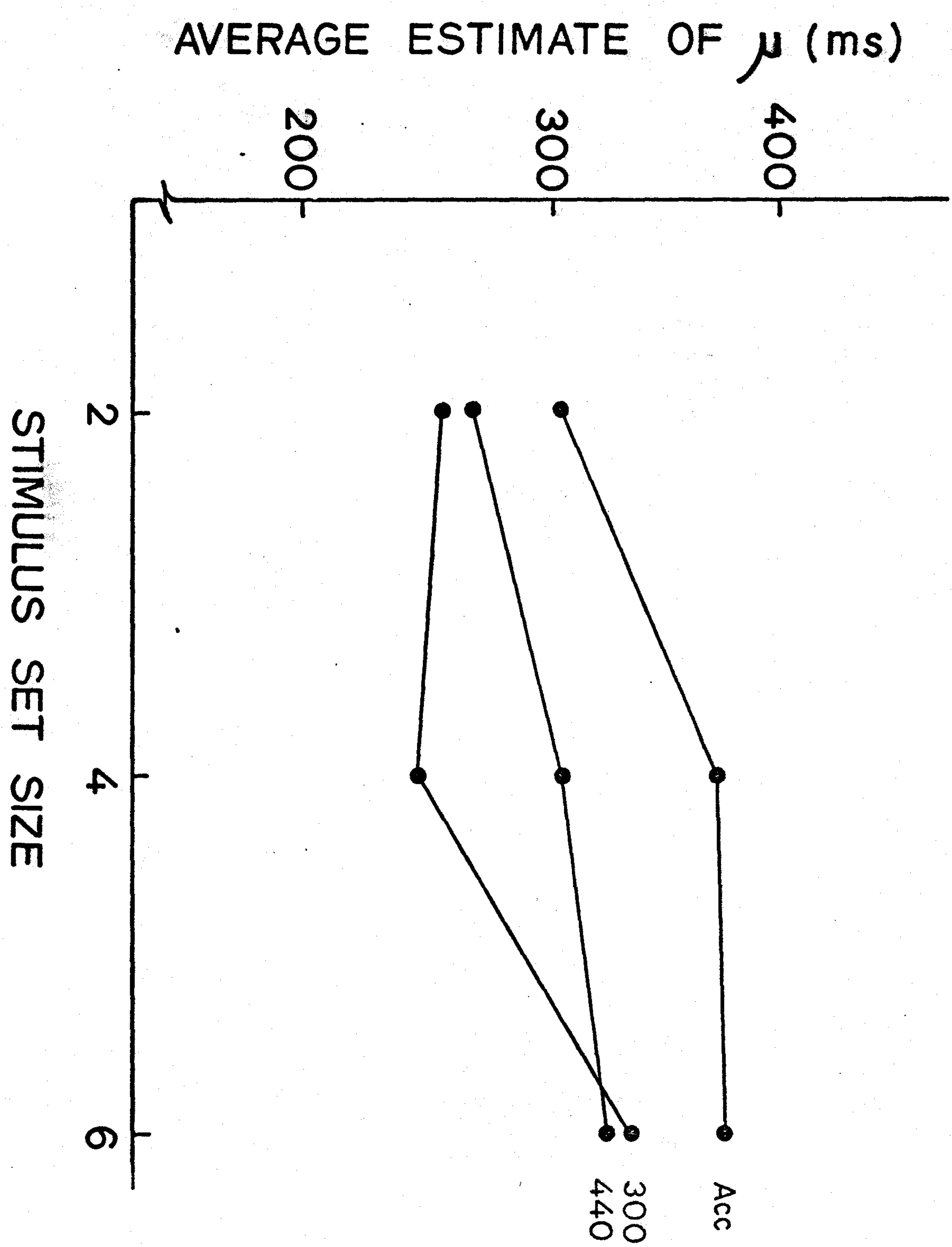

Figure 10. Average estimates of μ_i (based upon T1), obtained from Table 20 by averaging μ_i across response i for each stimulus set size and time deadline.

distributions for a given stimulus were combined across responses. The frequency distributions are presented in the appendices. From the distributions for individual stimuli, average distributions were obtained for each time deadline by combining the correct response distributions across stimuli and the error response distributions across stimuli for each time deadline and stimulus set size. To further increase stability, the time interval of the frequency distributions was increased to 50 ms by combining adjacent intervals in the average distributions. The average frequency distributions for the 6, 4 and 2 stimulus set conditions are presented in Tables 21, 22 and 23, respectively.

Insert Table 21

In Table 21 in the 300 ms condition, the distribution indicates that the response times are bimodally distributed. One mode occurs at about 175 ms and another at about 625 ms. The tail of the distribution beyond 650 ms is large and is still quite substantial at 1000 ms. The distributions for the accuracy and 440 ms conditions are unimodal.

The frequency distributions for the 4 stimulus set condition are similar to those of the 6 stimulus set except that the second mode occurs at about 575 ms. For the 2 stimulus set condition, the distribution within the 300 ms condition is unimodal with the mode at 200 ms. There is a large upper tail past 550 ms. In contrast, the 440 ms condition for the 2 stimulus set has a mode at 375 with a smaller upper tail.

Insert Tables 22 and 23

Table 21

Average correct and error response latency frequency distributions for the 6 stimulus set conditions at the time deadlines: 300 ms, 440 ms and accuracy. The distributions are in 50 ms intervals.

6 Stimulus Set

	300 ms		440 ms		Accuracy	
	Correct	Error	Correct	Error	Correct	Error
	0	0	2	2	0	0
100	180	924	19	122	2	2
	488	2770	94	443	5	26
200	552	2798	167	770	18	68
	392	2058	259	1139	19	82
300	282	1310	298	1052	28	117
	191	669	488	895	98	122
400	189	317	1650	914	664	172
	180	185	2251	697	2066	231
500	216	98	918	324	1548	113
	270	59	616	126	1759	65
600	287	39	468	65	1749	56
	302	31	456	42	1562	63
700	211	23	350	27	1207	36
	191	26	261	19	991	24
800	158	15	223	16	703	13
	135	12	222	9	589	12
900	113	11	168	5	434	24
	109	3	152	6	336	7
1000	376	28	448	16	1159	25
	4822	11376	9510	6689	14942	1258

Table 22

Average correct and error response latency frequency distributions for the 4 stimulus set conditions at the time deadlines: 300 ms, 440 ms and Accuracy. The distributions are in 50 ms intervals.

4 Stimulus Set

	300 ms		440 ms		Accuracy	
	Correct	Error	Correct	Error	Correct	Error
	0	3	0	1	0	1
100	143	463	21	79	0	1
	484	1505	88	248	6	15
200	523	1647	154	486	9	36
	408	1363	213	653	15	43
300	285	839	259	623	35	54
	203	367	471	523	112	82
400	181	186	1320	492	653	111
	182	83	1524	344	1481	122
500	207	61	742	96	1329	80
	235	40	463	48	1337	40
600	267	21	384	26	1267	29
	241	14	355	21	1004	25
700	150	18	254	12	669	22
	133	12	199	6	488	11
800	87	7	127	4	325	11
	90	6	120	4	289	3
900	68	6	101	1	217	4
	49	4	60	1	170	5
1000	205	14	272	5	687	12
	4141	6659	7127	3673	10093	707

Table 23

Average correct and error response latency frequency distributions for the 2 stimulus set conditions at the time deadlines: 300 ms, 440 ms and Accuracy. The distributions are in 50 ms intervals.

2 Stimulus Set

	300 ms		440 ms		Accuracy	
	Correct	Error	Correct	Error	Correct	Error
	0	0	0	0	0	0
100	88	94	13	6	1	0
	350	386	41	46	6	2
200	530	529	128	129	14	16
	531	486	239	233	57	46
300	401	316	479	270	134	71
	349	124	944	181	658	65
400	287	38	1153	42	1153	28
	209	13	559	12	962	11
500	157	7	270	8	666	1
	150	11	156	6	518	6
600	74	3	111	2	316	1
	63	1	97	3	208	0
700	50	4	73	0	126	0
	26	0	57	1	65	2
800	21	1	29	2	49	0
	14	0	33	0	51	0
900	18	2	14	1	36	0
	12	2	11	0	25	1
1000	53	0	51	0	105	0
	3383	2017	4458	942	5150	250

None of the frequency distributions for the error responses are biomodal. In most cases, the mode of the error response distributions occurs at the same point as does the first mode of the correct response distributions.

The presence of bimodality in the latency distributions for correct responses under the 300 ms time deadline suggests that perhaps two kinds of events are represented in the distribution. One kind of trial is very fast with an average latency which is the same as corresponding error responses. The other kind of trial is much slower with an average latency which is approximately the same as the average latency in the accuracy condition.

It is possible that the subjects found the 300 ms time deadline too stringent for this task. In order to comply with the 300 ms deadline, the subjects may have had to preselect a response and execute a guess. On some proportion of the 300 ms trials, however, the subjects might ignore the deadline and respond as if under an accuracy set. Subjects could ignore the time deadline because they wished to increase their accuracy or because they neglected to note a change in time deadline from trial to trial within some sequences. This strategy is exactly the strategy described by the Fast Guess Model which was assumed above for the SRSM and RSM. According to the assumptions of the SRSM, the time deadline was ignored on about 16% of the 300 ms deadline trials (see Table 9).

The above results suggest that the concept of two classes of states, SCR-like states and guessing states, is tenable for this experiment. However, the changes in μ across time deadlines suggest that the SCR state is not a unitary process and may include a mechanism that provides for a tradeoff between speed and accuracy. The large estimates of μ which occur in the 300 ms deadline condition, however, would seem to contradict the argument for a tradeoff within the SCR state. However, if subjects were never able to emit responses from the SCR state sufficiently fast to beat the time deadline, a binary strategy (Fast Guess) between an accurate SCR process and a guessing process could develop. That is, if 300 ms is less than the minimum time required to enter the SCR state, begin processing the stimulus and output a response, then subjects could not learn to reduce the duration of stimulus processing sufficiently to increase accuracy above chance and to still respond within the deadline. Subjects would always respond from the guessing state unless they ignored the time deadline and remained in the SCR state from the previous trial. This Fast Guess strategy is reminiscent of the results of Swensson (1968) and Swensson and Edwards (1968) which found that under certain conditions of strict time constraints subjects could not tradeoff speed against accuracy. Responses were either fast and at chance levels or slow and accurate.

It would be possible to test the hypothesis of a Fast Guess strategy if there existed an independent way of manipulating the proportion of guesses within the 300 ms condition. One *post hoc* procedure might be to investigate the effects of the time deadline and response correctness of trial n-1 on the performance of trial n. There is no *a priori* reason to suppose that sequential dependencies will occur from one deadline to another. In fact, unpublished results of Link and Tindall in a binary choice task suggested that subjects can readily change from one deadline to another without indication of sequential dependencies. However, since it was considered that the increased complexity in this task together with consideration of the response accuracy might produce some sequential effects, the following sequential analyses were performed.

Before analyses of the effects of time deadline - response accuracy are considered, an analysis of the effects of time deadline alone was made to determine whether this experiment would corroborate the earlier binary choice task. Sequential analyses were performed for each set size on all 6 subjects combined. One trial transitions were examined for each time deadline and correct and error latencies were combined. Estimates of probability correct and mean latency for each time deadline on trial n were obtained, conditional on the time deadline of trial n-1. The estimates are presented in Table 24 for the three set sizes. Both probability correct and mean latency are invariant within the deadline on trial n across the deadline conditions of trial n-1. These results therefore corroborate the earlier unpublished ones of Link and Tindall in which subjects could readily change from deadline to deadline with no apparent effects of the previous trial.

Insert Table 24

In addition to the above analyses, the following sequential analyses were performed on individual subjects and since the results were similar for all subjects, they were pooled. For each of the set sizes, one trial transitions were examined and for each time deadline, correct and error responses were examined separately. Therefore six classes of trials were determined (3 deadlines X 2 levels of accuracy). Probability correct,

Table 24

Estimates of probability correct and mean latency for each of the three time deadlines on trial n for a given time deadline on trial n-1.

Time Deadline on Trial n-1		A	440	300
		Stimulus Set Size 6		
A	Pc	.930	.582	.305
	M	629	425	290
440	Pc	.923	.590	.296
	M	617	429	293
300	Pc	.914	.589	.291
	M	620	421	285
		Stimulus Set Size 4		
A	Pc	.945	.649	.384
	M	598	425	297
440	Pc	.931	.679	.396
	M	590	430	298
300	Pc	.928	.652	.371
	M	594	413	287
		Stimulus Set Size 2		
A	Pc	.957	.826	.611
	M	461	371	275
440	Pc	.954	.833	.645
	M	458	372	283
300	Pc	.950	.818	.624
	M	462	369	283

Time Deadline on Trial n (column heading above) mean correct and mean error response latencies for each time deadline on trial n were obtained conditional on each of the six types of trials for trial n-1. The results are presented in Tables 25, 26 and 27 for the set sizes 6, 4 and 2, respectively. The bracketted numbers in each cell represent the frequency upon which response probability was based.

Insert Table 25

Of most importance for the binary strategy hypothesis are the results in the 300 ms condition on trial n. As can be seen in Table 25, for example, probability varies from .264 to .373 and mean correct latency from 429 to 542 ms. Mean error latency is relatively constant across all 300 ms conditions. These observations indicate that a considerable change occurs in the proportion of trials from the SCR state. Similar results obtain for the 4 stimulus set size condition in Table 26 but there do not appear to be substantial dependencies in the 2 stimulus condition. The latter result agrees with the earlier one of Link and Tindall.

Insert Tables 26 and 27

For each of the conditions in Tables 25, 26 and 27, estimates of average μ were obtained. Since some of the conditions were represented by relatively few observations the estimates of μ were more variable than they were for the earlier tests of μ across stimuli. Estimates of average μ are presented in Table 28. Except for one estimate in the 4 stimulus set condition, the estimates of μ are relatively constant within set size.

Table 25

Estimates of probability correct, mean correct and mean error response latencies for trial n, given a time deadline - response correctness condition for trial n-1. The numbers in brackets represent the frequency upon which response probability is based. For the 6 stimulus condition.

Trial n-1 Condition		Time Deadline For Trial n: A	440	300
Ac	Pc	.931 (4964)	.574 (4921)	.300
	Mc	643	514	476
	Me	443	293	204
440c	Pc	.923 (3244)	.620 (3075)	.291
	Mc	602	499	470
	Me	423	321	203
300c	Pc	.913 (1583)	.583 (1703)	.359
	Mc	668	525	542
	Me	406	286	219
Ae	Pc	.912 (434)	.677 (409)	.373
	Mc	649	554	538
	Me	420	343	221
440e	Pc	.923 (2246)	.549 (2230)	.303
	Mc	671	530	514
	Me	505	298	221
300e	Pc	.916 (3729)	.592 (3860)	.264
	Mc	627	488	429
	Mc	410	320	206

Table 26

Estimates of probability correct, mean correct and mean error response latencies for trial n, given a time deadline - response correctness condition for trial n-1. The numbers in brackets represent the frequency upon which response probability is based. For the 4 stimulus condition.

		Time Deadline For Trial n		
Trial n-1 Condition		A	440	300
	Pc	.948 (3469)	.645 (3268)	.385 (3355)
Ac	Mc	603	496	446
	Me	452	286	199
	Pc	.926 (2390)	.698 (2327)	.396 (2404)
440c	Mc	580	490	410
	Me	431	299	213
	Pc	.925 (1338)	.633 (1442)	.414 (1356)
300c	Mc	628	499	457
	Me	354	275	222
	Pc	.900 (239)	.699 (236)	.365 (233)
Ae	Mc	638	537	535
	Me	465	333	230
	Pc	.939 (1255)	.640 (1173)	.395 (1251)
440e	Mc	639	500	449
	Me	453	291	222
	Pc	.929 (2111)	.664 (2352)	.343 (2201)
300e	Mc	598	464	371
	Me	417	303	212

Table 27

Estimates of probability correct, mean correct and mean error response latencies for trial n, given a time deadline-response correctness condition for trial n-1. The numbers in brackets represent the frequency upon which response probability is based. For the 2 stimulus condition.

Trial n-1 Condition		Time Deadline For Trial n: A	440	300
Ac	Pc	.959 (1721)	.829 (1746)	.609 (1681)
	Mc	466	394	318
	Me	301	255	203
440c	Pc	.960 (1568)	.845 (1471)	.638 (1418)
	Mc	460	390	316
	Me	319	268	207
300c	Pc	.945 (1082)	.806 (1121)	.645 (1183)
	Mc	470	392	336
	Me	294	260	219
Ae	Pc	.913 (80)	.770 (87)	.651 (86)
	Mc	503	398	356
	Me	343	292	233
440e	Pc	.923 (339)	.771 (293)	.677 (310)
	Mc	489	409	364
	Me	303	268	209
300e	Pc	.958 (614)	.837 (681)	.590 (719)
	Mc	471	393	298
	Me	296	275	217

The one deviant estimate of μ is based upon only 233 observations. The estimates of μ averaged across the conditions of trial n-1 and estimates of average deviation across conditions of trial n-1 are also presented in Table 28.

Insert Table 28

The results of this sequential analysis support the hypothesis that subjects operated according to a Fast Guess strategy within the 300 ms deadline condition and the estimate of μ remained relatively constant across changes in the proportion of SCR trials. Also, these results indicate that there is a limit upon the ability of subjects to tradeoff speed against accuracy in the SCR state. For intermediate time deadlines subjects can adjust the parameters of the SCR state to stay within the constraints of a time deadline most of the time and optimize accuracy. For very short time deadlines adjustment does not appear to be possible and a very different strategy occurs.

Table 28

Estimates of average μ for trial n, conditional on the time deadline-response correctness condition of trial n-1, for each time deadline and set size. Estimates of average μ and average deviation of μ across the conditions of trial n-1 are also presented.

Estimates of μ for Trial n

Stimulus Set Size

Trial n-1 Condition	6			4			2		
	Time Deadline			Time Deadline			Time Deadline		
	A	440	300	A	440	300	A	440	300
Ac	646	553	714	606	543	672	473	430	524
440c	605	524	724	584	522	546	466	417	459
300c	673	565	721	636	553	667	481	434	479
Ae	654	576	699	645	571	956	520	443	498
440e	674	564	764	643	548	686	506	469	505
300e	631	515	710	603	497	652	479	422	483
Average μ	647	550	722	620	539	697	488	436	491
Average Deviation	22	20	15	22	20	86	17	13	18

CHAPTER FIVE

Discussion

The above tests indicate that the RSM is more capable of describing the results of this experiment than is the SRSM. The SRSM failed to satisfy the test of quasi-independence in the error probability matrices while the RSM did not predict quasi-independence. Also, the error probabilities in Tables 2 and 3 appeared to decrease away from the diagonal cells as is consistent with the RSM. These trends in error probabilities could also be predicted by the models proposed by Fitts (1954) and Crossman (1957) for scatter of responses and would be predicted by many theories of discrimination and recognition if proximity on the response panel is assumed to be related to similarity (e.g. Coombs, 1964; Luce, 1963; Luce and Galanter, 1963; Torgerson, 1958). The trends in the estimates of b_i calculated from equations (2') and (5') of the SRSM and the trends in the estimate of V_i from equation (4') are consistent with the RSM under assumptions 1-6. The hypothesis of invariance of P_k across stimulus-response pairs and stimulus set sizes was rejected. Also there were trends in P_k estimated according to equation (5'). P_k tended to decrease toward the diagonals. These trends in $Pc_i - Pe_{ji}$ are consistent with equation (5) of the RSM under the assumptions that P_k is a constant and that a_{jik} approaches a_{iik} as j approaches i, that is, near the diagonal. The estimates of the mean of response i from the selection state, μ_i, were found to be invariant across changes in the stimulus, as predicted by the RSM. Also, estimates of average μ within a time deadline were found to be invariant when the proportion of SCR responses on trial n fluctuated due to the time deadline - response correctness condition of trial n-1. However, the invariance of μ_i was rejected across changes in stimulus set size and time deadline.

<u>Failure of Invariance of μ_i Across Time Deadlines:</u>

The changes in μ_i which occurred across time deadlines were a little less straightforward than they were across stimulus set size. The estimates of μ_i for the accuracy condition were all larger than the estimates of μ_i for the 440 ms condition at each stimulus set size. However, the estimates of μ_i for the 300 ms time deadline were also larger than those for the 440 ms time deadline. There was no consistent difference between μ_i for the accuracy and μ_i for the 300 ms condition. As was noted earlier, this result was initially puzzling since in all of the experiments of Link and Tindall (1970, 1971) the estimates of μ, ordered themselves with respect to the time deadlines.

The changes in μ_i across time deadlines could be interpreted to indicate that the subject can control his response time in the response selection state as well as the proportion of trials in which the response selection state is entered. Perhaps, the processing in the response selection state can be described by an information processing model in the tradition of the random walk models of Stone (1960), Edwards (1965) and Laming (1968). The subject could control his response time in the response selection state by adjusting the boundaries of the random walk such that the walk would terminate on the average before the time deadline was exceeded. There is some question as to the value of retaining the notion of guessing and SCR processes if the SCR process represents a wide variety of levels of information processing. The guessing state could be represented in sequential processing models by decision criteria which are moved into or very near the initial point of the random walk.

The large estimates of μ in the 300 ms deadline condition appear to result from the subjects' inability to restrict the duration of processing in the SCR state sufficiently to increase his accuracy beyond a chance level and still respond before the 300 ms time deadline. The large estimates of μ occur because on a small percentage of 300 ms trials, subjects do not obey the deadline instructions and operate as if under an accuracy set. The analysis of sequential effects illustrates that the conditions of the previous trial influence the tendency to ignore the 300 ms deadline instruction.

Swensson (1968) and Swensson and Edwards (1968) encountered similar difficulties in obtaining a speed-accuracy tradeoff in tasks in which the payoff function for time and accuracy was rather complex. Subjects required an initial minimum "free" time before they were able to tradeoff speed for accuracy. Without this initial "free" time on every trial, subjects either operated at chance level or were very accurate. No intermediate levels of speed or accuracy occurred. Perhaps for the present task, too, 300 ms falls below some minimum time necessary for any information processing to occur.

As outlined in the introduction, the changes in μ_i across time deadlines also have implications for the template matching and feature testing models. Since the time spent in the processing state, whether we wish to consider it stimulus processing as Hick (1952) and Sternberg (1963, 1964, 1966) do or response selection as was done here, was dependent upon the time deadline, the types of processes considered to occur in the processing state must be capable of partial analysis. Therefore, template matching processes which assume complete analysis of the stimulus (Smith, 1968) are inappropriate. As discussed earlier, if the template matching process is considered to be a sequential comparison process through the possible alternatives and the subject capable of eliminating alternatives such that when the time deadline is reached he can respond (guess) from among a smaller set of alternatives, then the template matching process might be tenable. This process would require some internal timing mechanism to keep track of the time deadline. This proposal would have difficulty explaining the changes in μ_i for a stimulus set size of 2. If the set of alternatives were reduced at all the subject could respond correctly. Also, a serial search process which can eliminate alternatives and operate in terms of a reduced set of possibilities does not appear to be consistent with the nature of the mechanism proposed by Sternberg (1969a). Perhaps, a form of partial serial search can be developed which in the limits of an accuracy-oriented set will approach the mechanism Sternberg proposed.

Although feature testing models have not been constructed to account for speed-accuracy relationships, it is conceivable that speed-accuracy relationships could be described by incomplete feature testing processes. The subject could be assumed to have an internal timing device to keep track of the time deadline. He could be assumed to select a response on the basis of the number of alternatives which have not been eliminated by the number of features tested when the time deadline has expired. The feature testing search could be serial, alternative by alternative or it could be simultaneous if the test of each feature eliminated alternatives. The simultaneous search would require a form of hierarchical tests in which each test determines a subsequent branching in the hierarchy. This possibility was discussed by Smith (1968) as one type of feature testing model.

In order to attempt to account for the large estimates of μ in the 300 ms condition, the hypothesis of missed buttons was entertained. Analysis of the bivariate distributions of T1 and T2 provided no evidence for missed buttons. The similarity of the form of curves for estimates of μ in Figures 9 and 10 and the small average deviations in μ across stimuli further suggested that movement times did not play a significant role in the conclusions of this experiment. The analysis of the distribution of T1 + T2 revealed a bimodal distribution for the 300 ms condition. It was suggested that bimodality resulted from a mixture of many Fast Guess type responses and relatively few slow SCR type responses. The analysis of the sequential effects of the time deadline-response correctness condition of trial n-1 on the performance of trial n, provided evidence for experimenter controlled effects upon use of the SCR state. The estimates of μ across conditions of trial n-1 were relatively invariant and suggested more support for the mixture theory within time deadlines. The similarity of the results in the 300 ms condition to those of Swensson (1968) and Swensson and Edwards (1968) under strict time constraints further argues against a missed button interpretation for the present experiment. The above arguments against the missed buttons hypothesis, however, do not prove that missed buttons did not occur and that some different experimental procedure might yield results not consistent with those presented here.

Failure of Invariance of μ_i Across Stimulus Set Size:

Across changes in stimulus set size the estimate of μ_i decreased as the set size decreased. This result could be interpreted as indicating that the response selection process consists of a serial search through a set of response alternatives. As the set is decreased in size the number of alternatives which must be searched is also reduced. A serial search would predict that estimates of μ_i should decrease linearly with stimulus set size. Although the curves through the points for each time deadline in Figure 9 are not linear, the linear fit would be quite good. Some caution must be taken in the interpretation of these curves. If we assume, as suggested above, that a tradeoff of speed for accuracy can occur in the SCR state, then the estimates of P_k $(a_{iik} - a_{jik})$ as well as μ would have to be taken into consideration in models for the response selection process.

Another possible interpretation of the changes in μ_i across stimulus set size might be that the search consists of a simultaneous search of features of the response alternatives in the manner of the feature testing models of stimulus categorization. If the number of response alternatives is decreased then, perhaps the subject can distinguish between the response alternatives with shorter feature lists. That is, fewer features are necessary to distinguish between the alternatives. If the features are chosen to be maximally discriminable then each feature should eliminate half of the response alternatives. This proposal would predict that the estimates of μ_i should be a logarithmic function of the stimulus set size. The points for the accuracy and 440 ms conditions in Figure 9 are approximately logaritmic functions of set size but the 300 ms deadline condition does not support the logarithmic prediction. Several other alternate explanations could be proposed, here, for the relationships between stimulus set size and μ (e.g. Falmagne, 1965; Rummelhart, 1970).

The review of models of CRT which was presented in the introduction and in the recent papers by Smith (1968) and Welford (1960), all indicate the importance of the notion of processing stages in current conceptions of the events involved in CRT tasks. However, it was also noted that the models have been concerned with a single processing stage, usually the recognition or categorization stage. The SRSM and RSM were designed to investigate a single processing stage, the response selection stage. It was suggested above when the recent research of Link and Tindall (1970, 1971), Ollman (1966) and Yellott (1967, 1971) was introduced, that in some classes of experiments the implicit assumption that only a single processing stage is involved may be invalid. In the binary choice CRT tasks with highly discriminable stimuli (e.g. Ollman, 1966; Yellott, 1967, 1971), perhaps, only the response selection stage takes a substantial proportion of the RT. In the discrimination tasks of Link and Tindall (1970, 1971), it was argued that the stimulus categorization and response selection stages might be involved. If the two stages did not completely overlap in time and if the stages were not identically affected by the motivation imposed by time deadlines then perhaps a more complex two-stage model might account for the changes in the estimates of the parameters of the SCR state which were found in the experiments by Link and Tindall (1970, 1971). Also, if it is assumed that increasing the stimulus set size would also magnify the operations of the stimulus categorization stage so that each of the categorization and response selection stages are responsible for large proportions of the CRT then perhaps a two stage model would also account for the changes in parameters of the SCR state which were obtained in the present CRT tasks.

To investigate the above hypothesis, the following theoretical development is presented. The class of models which will be considered are two-stage recognition-response selection models. This class of models is similar in spirit to the Fast Guess Model, the SRSM and RSM, because it incorporates the notion of mixing of classes of states. This theoretical development is important because it seems to be the simplest way that the two state model can be extended to account for changes in the SCR state. For these two-stage models, there is assumed to be a recognition stage and a response selection stage. The operations of these stages do not completely overlap in real time. It is proposed that motivation for speed or accuracy may result in either deletion of the response selection stage or the recognition <u>and</u> response selection stage. That is, under high motivation for accuracy the subject will enter the recognition stage and subsequently enter the response selection stage. As motivation for speed is increased, the subject may enter the recognition stage but on some proportion of the trials he will not enter the response selection stage but will enter a guessing state (G1). If motivation for speed is further increased, the subject may also delete the recognition stage and enter immediately into a guessing state (G2). The parameters of the two types of guessing states will, for the purposes of generality, be assumed to differ. It was considered that these two types of guessing states might reflect different processes. Possibly, the guessing state (G1) which follows recognition might reflect the expected probability structure of the trial events while the guessing state (G2) which occurs at initiation of the trial might reflect the events of the immediately preceeding trial (e.g. sequential effects of repetitions or feedback of previous trial, etc.) While this possibility is used as a justification for considering two types of guessing states, it is first necessary to see whether the two stage model can adequately account for the present experimental results.

The Two-Stage Recognition-Response Selection Model

A stimulus i is presented with probability π_i. With probability P_k the stimulus is processed in the stimulus recognition state and with probability $1 - P_k$, the stimulus is not processed and a response j is guessed with probability b_j. If the stimulus is processed in the recognition state, stimulus i is categorized as stimulus j with probability a_{ij}. After the stimulus is categorized, the categorized information enters a response selection state with probability, Q_k, and response m is selected with probability, c_{jm}, or response selection is omitted and the subject may guess response m with probability d_m. The means of the latency distributions associated with: the combined stimulus recognition-response selection stages are L_{ijm}, for stimulus i, categorization j and response m; the stimulus recognition stage followed by guessing are D_{ijm}, for stimulus i, categorization j and response m; the guessing state alone G_j. The subscripts i, j and m go from 1 to n, where n is the total number of stimulus-response alternatives. The probability tree diagram which illustrates the model is presented in Figure 11. The tree is resticted to only 2 stimulus-response alternatives for simplicity.

Insert Figure 11

A number of derivations can be obtained from this model:

The probability that the subject will make response i, given that stimulus i is presented, is equal to the sum of two components, one from the stimulus categorization process and one from the guessing process. The component from the stimulus categorization process consists of the sum of n subprocesses, where n is the number of stimulus alternatives. Each of the n subprocesses represents a two stage process: stimulus categorization - response selection. Each subprocess represents the probability, P_k, that the subject enters the stimulus categorization stage times the probability, a_{im}, that stimulus i will be categorized as stimulus m. From the categorization stage with probability, Q_k, the subject enters the response selection stage and selects response i with probability, c_{mi}, and with probability, $1 - Q_k$, the subject enters a second level of guessing and guesses response i with probability, d_i. The n subprocesses occur when m can take on all values from 1 to n. The guessing component of probability correct is represented by the probability, $1 - P_k$, of entering the guessing states times the bias probability, b_i, of making response i. Probability correct can be represented formally as:

$$P_{ii} = P_k \sum_{m=1}^{n} a_{im} (Q_k c_{mi} + (1 - Q_k) d_i + (1 - P_k) b_i \qquad (10)$$

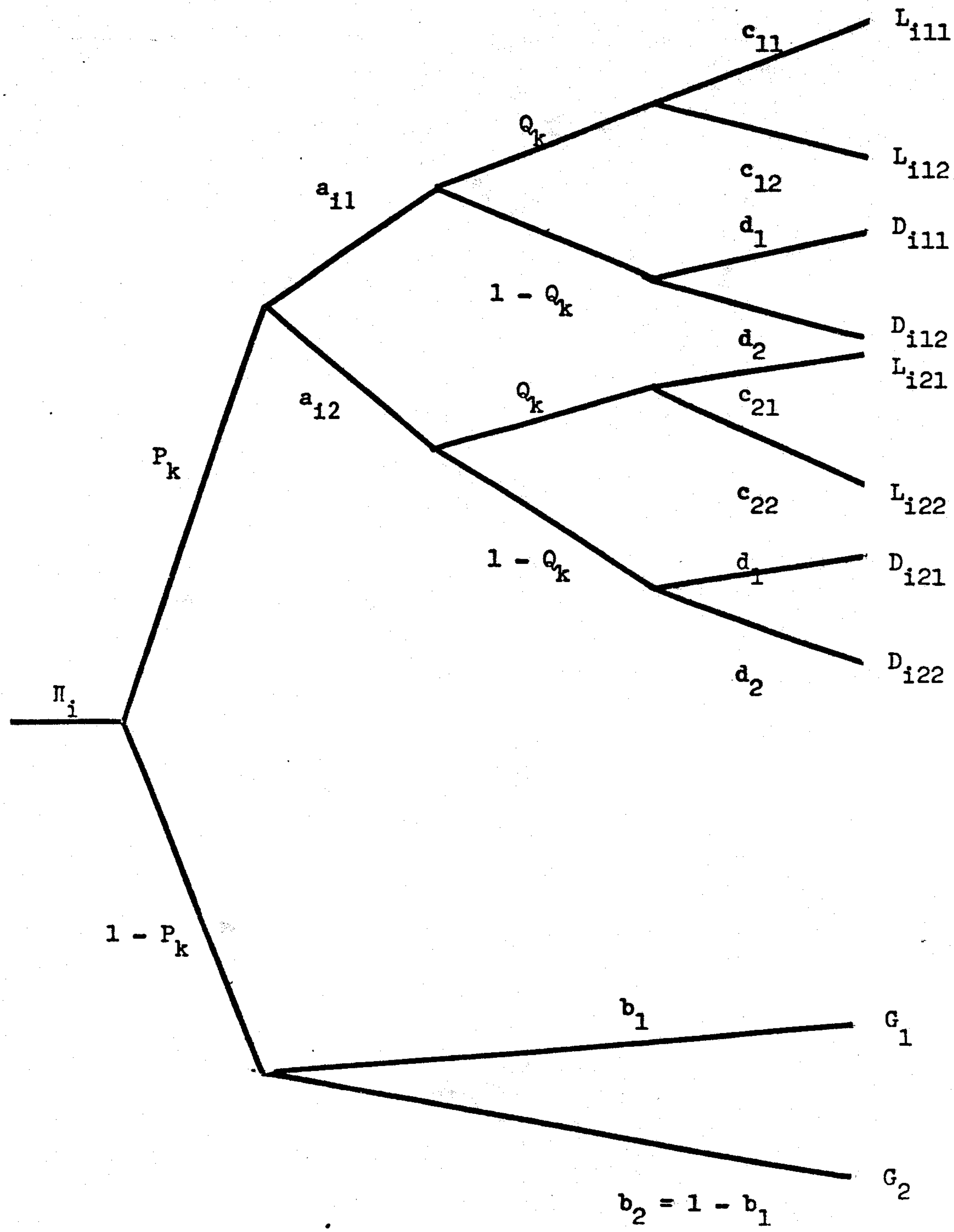

Figure 11. The Two-Stage Recognition-Response Selection Model.

Similarly, the probability that the subject will make response i, given that stimulus j is presented, is equal to the sum of two components, one from the stimulus categorization process and one from the guessing process. The stimulus categorization component consists of the sum of n subprocesses. Each subprocess is represented by the probability, P_k, of entering the categorization process times the probability, a_{jm}, that stimulus j is categorized as stimulus m. From the categorization stage with probability, Q_k, the subject enters the response selection stage and selects response i with probability, c_{mi}, and with probability, $1 - Q_k$, the subject enters the second level of guessing and guesses response i with probability, d_i. Again, the n subprocesses occur when m takes on all values from 1 to n. The guessing component of probability correct is represented by the probability, $1 - P_k$, of entering the guessing state times the bias probability, b_i, of making response i. The probability of making response i given stimulus j can be represented formally as:

$$P_{ji} = P_k \sum_{m=1}^{n} a_{jm} (Q_k c_{mi} + (1 - Q_k) d_i) + (1 - P_k) b_i \qquad (11)$$

Similarly, derivations can be obtained for the probability of response i, given stimulus i, times the mean latency for response i, given stimulus i, which can be written formally as:

$$P_{ii} M_{ii} = P_k \sum_{m=1}^{n} a_{im} (Q_k c_{mi} L_{imi} + (1 - Q_k) d_i D_{imi}) + (1 - P_k) b_i G_i \qquad (12)$$

And the derivation for probability of response i, given stimulus j, times the mean latency for response i given stimulus j can be written formally as:

$$P_{ji}M_{ji} = P_k \sum_{m=1}^{n} a_{jm} (Q_k c_{mi} L_{jmi} + (1 - Q_k) d_i D_{jmi}) + (1 - P_k) b_i G_i \tag{13}$$

If equation (11) is subtracted from equation (10) then:

$$P_{ii} - P_{ji} = P_k Q_k \sum_{m=1}^{n} (a_{im} - a_{jm}) c_{mi} > 0, \text{ for all } i \neq j \tag{14}$$

If equation (13) is subtracted from equation (12) then:

$$P_{ii}M_{ii} - P_{ji}M_{ji} = P_k (Q_k \sum_{m=1}^{n} (a_{im} L_{imi} - a_{jm} L_{jmi}) c_{mi} + (1 - Q_k) d_i \sum_{m=1}^{n} (a_{im} D_{imi} - a_{jm} D_{jmi})) \tag{15}$$

If equation (15) is divided by equation (14) then:

$$(P_{ii}M_{ii} - P_{ji}M_{ji})/(P_{ii} - P_{ji}) = Z_{ij} + T_{kij} \tag{16}$$

where

$$Z_{ij} = \frac{\sum_{m=1}^{n} (a_{im} L_{imi} - a_{jm} L_{jmi}) c_{mi}}{\sum_{m=1}^{n} (a_{im} - a_{jm}) c_{mi}}$$

which is independent of time deadline, and where

$$T_{kij} = \frac{(1 - Q_k) d_i}{Q_k} \; \frac{\sum_{m=1}^{n} (a_{im} D_{imi} - a_{jm} D_{jmi})}{\sum_{m=1}^{n} (a_{im} - a_{jm}) c_{mi}}$$

which will be influenced by time deadlines. Since only T_{kij} can be influenced by time deadlines, the calculation in equation (16) can only be altered through T_{kij} when time deadlines are varied and i and j fixed.

Two simplifying assumptions are made in order to make the model more mathematically manageable.

<u>Assumption 1'</u>: If stimulus i is presented and the recognition state categorizes it as stimulus j, for $i \neq j$, then on the average the amount of additional time required is α units more than if stimulus i is categorized as stimulus i, for all values of i. (it is possible that $\alpha \lessgtr 0$).

<u>Assumption 2'</u>: The latency distributions for responses when the response selection stage is omitted after stimulus recognition are identical for a given response i except for constant α as specified in Assumption 1'. Therefore,

$$D_{imi} = D_{jmi}, \text{ for all } i \neq m \text{ and } j \neq m$$

$$D_{imi} = D_{mmi} + \alpha, \; i \neq m.$$

No obvious simple relationship between T_{kij} and changes in time deadlines has been proven for the general case of stimulus set size n. However, for n = 2, consider T_{kij} for i = 1 and j = 2:

$$T_{kij} = \frac{\alpha\,(1 - Q_k)\, d_1\, (a_{22} - a_{11})/(a_{11} + a_{22} - 1)(c_{11} + c_{22} - 1)}{Q_k}$$

and for $i = 2$ and $j = 1$:

$$T_{kij} = \frac{\alpha(1 - Q_k)(1 - d_1)(a_{11} - a_{22})/(a_{11} + a_{22} - 1)(c_{11} + c_{22} - 1)}{Q_k}$$

Since only the factor $d_i(a_{jj} - a_{ii})$ changes, then T_{kij} will be positive for one of the above cases and negative for the other (unless $a_{ii} = a_{jj}$). Therefore, the calculation in equation (16) which is identical to that of equation (7) would predict that for stimulus set size 2, the estimates of μ_i and μ_j in Table 4 would change in opposite directions as the time deadlines are altered. However, since all the estimates of μ_i decrease from the accuracy condition to the 440 ms condition and increase from the 440 to the 300 ms condition, there is no evidence of an opposition in the estimates of μ_i across time deadlines. At least for the 2 stimulus set, the two stage model does not account for changes in μ_i across time deadlines.

While the two stage model seemed to offer an intuitively reasonable alternative to the RSM, the quantitative predictions which were presented above indicate that this type of two stage process is inadequate for the experiments discussed in this paper.

Conclusion

While it was the initial anticipation that this research would suggest an explanation for the difference in results between the research of Link and Tindall (1970, 1971) and Ollman (1970) and those of Ollman (1966) and Yellott (1967, 1971), this rapprochement has not been forthcoming. The binary choice Fast Guess Model of Ollman (1966) and Yellott (1967, 1971) was extended to a multiple choice task. In three choice-reaction time tasks, the invariance of estimates of the mean of the processor-controlled states was rejected. It was also shown that an extension of the theory to a particular two stage stimulus recognition - response selection process would not account for the results.

It would appear that the failure of invariance of processor-controlled latency distributions is a relatively general phenomenon and is not restricted to the discrimination tasks of Link and Tindall (1970, 1971) or to judgment of line lengths. Further theoretical developments should likely be pursued in the direction of incorporating information processing models into the processor-controlled states.

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Appendix Tables of Estimates of Response Probability for Individual Subjects. Table I is for set size 6 and Table II is for set size 4.

Table I

<u>Individual Subjects' Data</u>

Probability of response j given stimulus i for the time deadline conditions: Accuracy, 440 and 300 ms. The probabilities are based on 450 presentations of each stimulus. The stimulus set size within sessions was 6.

Subject 1

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.911	.073	.011	.000	.002	.002
	2	.011	.940	.020	.002	.027	.000
	3	.016	.013	.925	.045	.002	.000
	4	.005	.000	.096	.829	.058	.013
	5	.007	.020	.005	.036	.882	.051
	6	.005	.002	.000	.000	.082	.911

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.751	.171	.036	.020	.018	.005
	2	.033	.816	.058	.036	.053	.005
	3	.009	.020	.860	.107	.005	.000
	4	.002	.016	.093	.825	.056	.009
	5	.007	.031	.027	.078	.827	.031
	6	.018	.016	.018	.031	.196	.722

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.158	.065	.309	.207	.118	.145
	2	.151	.098	.338	.187	.098	.129
	3	.127	.047	.409	.196	.096	.127
	4	.138	.029	.327	.267	.122	.118
	5	.151	.033	.338	.225	.140	.113
	6	.178	.049	.302	.187	.131	.153

Subject 2

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.953	.005	.007	.007	.016	.013
	2	.009	.942	.002	.011	.020	.016
	3	.016	.013	.911	.018	.036	.007
	4	.009	.007	.018	.907	.053	.007
	5	.007	.011	.007	.007	.942	.027
	6	.018	.000	.005	.002	.031	.945

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.533	.087	.093	.049	.176	.062
	2	.098	.569	.058	.071	.158	.047
	3	.091	.107	.500	.098	.171	.033
	4	.087	.082	.098	.462	.222	.049
	5	.076	.116	.065	.078	.576	.091
	6	.118	.096	.067	.071	.178	.471

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.493	.091	.085	.069	.209	.053
	2	.076	.451	.089	.116	.185	.085
	3	.100	.107	.440	.098	.200	.056
	4	.131	.078	.107	.371	.262	.051
	5	.113	.067	.089	.091	.580	.060
	6	.120	.085	.069	.062	.200	.465

Subject 3

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.920	.018	.029	.018	.013	.002
	2	.002	.905	.025	.040	.027	.002
	3	.011	.009	.909	.053	.018	.000
	4	.007	.011	.069	.873	.040	.000
	5	.009	.013	.009	.016	.936	.018
	6	.007	.011	.029	.020	.038	.896

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.465	.073	.129	.116	.142	.076
	2	.078	.393	.151	.129	.160	.089
	3	.089	.136	.407	.176	.122	.071
	4	.051	.178	.198	.367	.129	.078
	5	.071	.102	.078	.107	.511	.131
	6	.062	.113	.136	.118	.147	.425

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.449	.093	.111	.111	.171	.065
	2	.082	.416	.160	.140	.133	.069
	3	.096	.107	.416	.187	.111	.085
	4	.082	.133	.176	.347	.193	.069
	5	.087	.133	.113	.116	.438	.113
	6	.107	.091	.140	.105	.149	.409

Subject 4

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.873	.005	.116	.000	.005	.002
	2	.007	.931	.000	.007	.056	.000
	3	.011	.002	.978	.009	.000	.000
	4	.000	.002	.016	.969	.009	.005
	5	.000	.071	.000	.007	.907	.016
	6	.000	.002	.000	.005	.016	.978

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.451	.053	.245	.109	.085	.058
	2	.053	.302	.047	.091	.449	.058
	3	.096	.058	.547	.136	.129	.036
	4	.013	.020	.058	.609	.198	.1022
	5	.009	.080	.033	.073	.742	.062
	6	.018	.020	.031	.067	.102	.762

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.131	.120	.200	.156	.251	.142
	2	.102	.156	.138	.176	.293	.136
	3	.085	.147	.205	.187	.265	.113
	4	.102	.142	.158	.218	.262	.118
	5	.091	.162	.120	.189	.309	.129
	6	.091	.149	.162	.147	.293	.158

Subject 5

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.965	.011	.005	.020	.000	.000
	2	.007	.973	.007	.011	.002	.000
	3	.000	.040	.918	.040	.002	.000
	4	.000	.002	.042	.949	.002	.005
	5	.002	.005	.002	.033	.942	.013
	6	.000	.000	.007	.009	.009	.976

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.469	.109	.093	.276	.045	.009
	2	.038	.560	.117	.209	.060	.016
	3	.018	.096	.520	.291	.062	.013
	4	.031	.053	.187	.680	.045	.005
	5	.027	.069	.158	.313	.405	.029
	6	.031	.116	.120	.240	.087	.407

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.176	.109	.247	.365	.091	.013
	2	.040	.273	.220	.371	.078	.018
	3	.029	.096	.400	.358	.091	.027
	4	.029	.102	.289	.487	.078	.016
	5	.027	.131	.265	.362	.207	.009
	6	.047	.129	.247	.365	.080	.133

Subject 6

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.976	.013	.005	.002	.005	.000
	2	.060	.862	.045	.011	.013	.009
	3	.016	.018	.893	.036	.022	.016
	4	.002	.005	.020	.882	.078	.011
	5	.002	.002	.005	.073	.867	.051
	6	.000	.005	.000	.000	.065	.931

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.900	.040	.011	.011	.020	.018
	2	.189	.558	.091	.098	.036	.029
	3	.053	.073	.625	.156	.053	.040
	4	.009	.013	.056	.736	.167	.013
	5	.018	.007	.036	.260	.565	.113
	6	.031	.000	.007	.042	.211	.707

Table I (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	.278	.060	.031	.122	.285	.222
	2	.209	.122	.040	.105	.316	.209
Stimulus	3	.225	.040	.116	.138	.293	.189
	4	.211	.042	.042	.176	.309	.220
	5	.189	.053	.036	.136	.373	.211
	6	.238	.042	.018	.138	.262	.302

Table II

Individual Subjects' Data

Probability of response j given stimulus i for the time deadline conditions: Accuracy, 440 and 300 ms. The probabilities are based on 300 presentations of each stimulus. The stimulus set size within sessions was 4.

Subject 1

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.940	.020	.017	.000	.010	.013
	2	.053	.870	.047	.003	.027	.000
	3	.007	.010	.943	.037	.000	.003
	4	.007	.003	.030	.907	.033	.020
	5	.013	.017	.013	.033	.870	.053
	6	.007	.003	.000	.010	.037	.943

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.867	.050	.040	.007	.007	.030
	2	.060	.743	.093	.017	.080	.007
	3	.023	.007	.853	.113	.000	.003
	4	.007	.003	.120	.807	.037	.027
	5	.007	.037	.010	.080	.813	.053
	6	.033	.007	.007	.063	.033	.857

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.377	.053	.083	.107	.107	.273
	2	.190	.257	.107	.087	.247	.113
	3	.163	.137	.290	.140	.137	.133
	4	.170	.163	.230	.190	.130	.117
	5	.153	.230	.100	.100	.293	.123
	6	.367	.110	.110	.040	.090	.283

Subject 2

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.957	.003	.007	.000	.010	.023
	2	.010	.933	.007	.007	.040	.003
	3	.003	.007	.967	.007	.013	.003
	4	.007	.000	.017	.953	.017	.007
	5	.000	.003	.000	.017	.977	.003
	6	.017	.000	.003	.000	.017	.963

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.713	.037	.020	.067	.090	.073
	2	.043	.590	.067	.083	.193	.023
	3	.030	.047	.660	.133	.097	.033
	4	.037	.030	.143	.653	.093	.043
	5	.070	.147	.067	.067	.617	.033
	6	.130	.040	.047	.030	.100	.653

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	.603	.050	.077	.053	.087	.130
	2	.063	.533	.097	.067	.213	.027
Stimulus	3	.077	.063	.593	.093	.123	.050
	4	.053	.033	.120	.610	.130	.053
	5	.057	.113	.070	.087	.633	.040
	6	.133	.077	.077	.043	.080	.590

Subject 3

Accuracy
Response

		1	2	3	4	5	6
	1	.950	.010	.017	.010	.010	.003
	2	.003	.887	.033	.020	.053	.003
Stimulus	3	.000	.003	.910	.067	.007	.013
	4	.000	.023	.043	.930	.003	.000
	5	.003	.013	.017	.033	.933	.000
	6	.003	.013	.007	.027	.037	.913

440 Ms
Response

		1	2	3	4	5	6
	1	.513	.080	.077	.117	.107	.107
	2	.040	.433	.127	.130	.207	.063
Stimulus	3	.057	.047	.500	.300	.040	.063
	4	.023	.063	.220	.570	.063	.060
	5	.030	.187	.070	.070	.577	.067
	6	.113	.070	.070	.113	.117	.517

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.553	.057	.080	.103	.107	.100
	2	.043	.460	.103	.107	.240	.047
	3	.037	.053	.487	.327	.050	.047
	4	.023	.090	.207	.517	.090	.073
	5	.070	.113	.107	.100	.533	.077
	6	.107	.077	.087	.113	.133	.483

Subject 4

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.940	.000	.047	.007	.003	.003
	2	.007	.897	.010	.013	.067	.007
	3	.007	.023	.933	.037	.000	.000
	4	.000	.000	.003	.980	.013	.003
	5	.003	.057	.000	.030	.910	.000
	6	.003	.003	.003	.020	.007	.963

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.577	.053	.147	.090	.093	.040
	2	.063	.407	.040	.117	.350	.023
	3	.043	.043	.713	.153	.040	.007
	4	.020	.007	.097	.753	.063	.060
	5	.020	.113	.050	.143	.637	.037
	6	.060	.030	.030	.087	.050	.743

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.237	.137	.123	.120	.143	.240
	2	.107	.227	.117	.163	.250	.137
	3	.087	.060	.247	.357	.113	.137
	4	.090	.083	.257	.307	.133	.130
	5	.083	.233	.147	.167	.280	.090
	6	.190	.127	.127	.157	.143	.257

Subject 5

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.973	.007	.003	.007	.010	.000
	2	.007	.970	.013	.000	.007	.003
	3	.000	.007	.953	.040	.000	.000
	4	.003	.000	.027	.963	.007	.000
	5	.003	.000	.007	.027	.947	.017
	6	.003	.007	.000	.013	.027	.950

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.520	.107	.100	.107	.107	.060
	2	.033	.600	.090	.107	.127	.043
	3	.033	.053	.553	.273	.063	.023
	4	.050	.033	.160	.693	.043	.020
	5	.047	.130	.133	.133	.520	.037
	6	.100	.117	.083	.133	.113	.453

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.303	.157	.137	.170	.163	.070
	2	.037	.413	.100	.210	.207	.033
	3	.073	.043	.413	.390	.043	.037
	4	.080	.053	.283	.503	.053	.027
	5	.070	.203	.173	.170	.357	.027
	6	.107	.210	.177	.157	.127	.223

Subject 6

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	.977	.003	.003	.003	.000	.013
	2	.030	.913	.020	.013	.017	.007
	3	.003	.010	.920	.053	.003	.010
	4	.003	.007	.017	.900	.057	.017
	5	.003	.010	.010	.070	.863	.043
	6	.010	.000	.003	.023	.020	.943

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.930	.007	.013	.007	.010	.033
	2	.073	.693	.077	.067	.073	.017
	3	.020	.073	.720	.137	.030	.020
	4	.000	.020	.087	.773	.083	.037
	5	.033	.027	.027	.117	.703	.093
	6	.030	.013	.010	.073	.040	.833

Table II (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	.407	.030	.050	.113	.043	.357
	2	.207	.140	.063	.120	.300	.170
	3	.113	.097	.160	.253	.203	.173
	4	.123	.103	.093	.340	.193	.147
	5	.183	.130	.067	.147	.280	.193
	6	.313	.030	.020	.163	.050	.423

Appendix Tables for Tests of Quasi-independence in Error Probability Matrices.

Table III

Estimates of b_i and $1\text{-}P_k$ were obtained by using Goodman's iterative procedure for tests of quasi-independence in the error probability matrices of Tables 2 and 3. The upper entry in each cell of the table represents the product of b_i and $(1\text{-}P_k)$. The second entry represents the expected frequency for the cell and the third entry represents the observed frequency.

6 Stimulus Condition
Accuracy

Responses

Stimuli		1	2	3	4	5	6
	$1\text{-}P_k$ / b_i	.0816	.1345	.2115	.2005	.2773	.0947
1	.1569		.0211 27 56	.0332 42 77	.0315 40 21	.0435 55 18	.0149 19 9
2	.1849	.0151 19 43		.0391 49 44	.0371 47 37	.0513 64 65	.0175 22 12
3	.2121	.0173 22 31	.0285 36 43		.0425 53 90	.0588 74 36	.0201 25 10
4	.2639	.0215 27 10	.0355 45 12	.0558 70 117		.0732 92 108	.0250 31 18
5	.2589	.0211 27 12	.0348 44 55	.0548 69 12	.0519 65 77		.0245 31 79
6	.1442	.0118 15 13	.0194 24 9	.0305 38 18	.0289 36 16	.0400 50 108	

Table III (Cont'd)

6 Stimulus Condition
440 Ms

Responses

Stimuli	$1-P_k$ / b_i	1	2	3	4	5	6
		.0993	.1458	.1733	.2442	.2473	.0901
1	.1803		.0263 177 240	.0313 211 273	.0440 297 261	.0446 300 218	.0163 109 102
2	.2192	.0218 147 220		.0380 256 235	.0535 360 285	.0542 365 412	.0197 133 109
3	.2055	.0204 137 160	.0300 202 220		.0502 338 433	.0508 342 244	.0185 125 87
4	.2047	.0203 137 87	.0298 201 163	.0355 239 310		.0506 341 367	.0184 124 115
5	.2107	.0209 141 93	.0307 207 182	.0365 246 178	.0515 347 409		.0190 128 206
6	.1839	.0183 123 125	.0268 181 162	.0319 215 170	.0449 302 256	.0455 306 414	

Table III (Cont'd)

6 Stimulus Condition
300 Ms

Responses

Stimuli		1	2	3	4	5	6
	$1-P_k$ / b_i	.1361	.1078	.1957	.2155	.2225	.1225
	.1975		.0213	.0386	.0426	.0440	.0242
1			242	440	484	500	275
			242	442	463	506	288
	.1988	.0271		.0389	.0428	.0443	.0244
2		308		443	487	503	277
		297		443	492	496	290
	.1975	.0269	.0213		.0426	.0440	.0242
3		306	242		484	500	275
		297	244		523	475	268
	.2085	.0284	.0225	.0408		.0464	.0255
4		323	256	464		528	291
		312	237	494		552	266
	.2010	.0274	.0217	.0393	.0433		.0246
5		311	247	447	493		280
		296	261	432	503		286
	.1975	.0269	.0213	.0386	.0425	.0439	
6		306	242	439	484	500	
		351	245	422	451	502	

Table III (Cont'd)

4 Stimulus Condition
Accuracy

Responses

Stimuli	$1-P_k$ / b_i	1	2	3	4	5	6
		.0853	.1161	.1753	.2645	.2498	.1091
	.1222		.0142	.0214	.0323	.0305	.0133
1			10	15	23	22	9
			13	28	8	13	17
	.2544	.0217		.0446	.0673	.0636	.0278
2		15		32	48	45	20
		33		39	17	63	7
	.1921	.0164	.0223		.0508	.0480	.0210
3		12	16		36	34	15
		6	18		72	7	9
	.2115	.0180	.0246	.0371		.0529	.0231
4		13	17	26		37	16
		6	10	41		39	14
	.2828	.0241	.0328	.0496	.0748		.0309
5		17	23	35	53		22
		8	30	14	63		35
	.1540	.0131	.0179	.0270	.0407	.0385	
6		9	13	19	29	27	
		13	8	5	28	43	

Table III (Cont'd)

4 Stimulus Condition
440 Ms

Responses

Stimuli	$1-P_k$	b_i 1	2	3	4	5	6
		.1053	.1424	.1892	.2527	.2121	.0984
1	.1716		.0244 90 100	.0325 119 119	.0434 159 118	.0364 134 124	.0169 62 103
2	.2413	.0254 93 94		.0457 168 148	.0610 224 156	.0512 188 309	.0237 87 53
3	.2018	.0213 78 62	.0287 106 81		.0510 187 332	.0428 157 81	.0199 73 45
4	.1913	.0202 74 41	.0272 100 47	.0362 133 248		.0406 149 115	.0188 69 74
5	.2212	.0233 86 62	.0315 116 192	.0419 154 107	.0559 205 183		.0218 80 96
6	.1760	.0185 68 140	.0251 92 83	.0333 122 74	.0445 163 150	.0373 137 136	

Table III (Cont'd)

4 Stimulus Condition
300 Ms

Responses

Stimuli	$1\text{-}P_k$ / b_i	1	2	3	4	5	6
		.1591	.1416	.1624	.1991	.1862	.1517
	.1886		.0267	.0306	.0375	.0351	.0286
1			178	204	250	234	190
			145	165	200	195	351
	.2084	.0331		.0339	.0415	.0388	.0316
2		221		225	276	258	210
		194		176	226	437	158
	.2049	.0326	.0290		.0408	.0382	.0311
3		217	193		272	254	207
		165	136		468	201	173
	.1988	.0316	.0282	.0323		.0370	.0301
4		210	187	215		246	201
		162	158	357		219	164
	.2006	.0319	.0284	.0326	.0399		.0304
5		212	189	217	266		203
		185	307	199	231		165
	.1986	.0316	.0281	.0323	.0395	.0370	
6		210	187	215	263	246	
		365	189	179	202	187	

Appendix Tables for

Tests of Invariance of

The Probability of Entering

The Response Selection State

Table IV

Individual Subjects' Data

Estimates of P_k obtained by subtracting the off-diagonal column entries from the diagonal column entry in Table I. The stimulus set size was 6.

Subject 1

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.867	.913	.829	.880	.909
	2	.900	----	.905	.827	.856	.911
	3	.896	.927	----	.785	.880	.911
	4	.907	.940	.829	----	.825	.898
	5	.905	.920	.920	.793	----	.860
	6	.907	.938	.925	.829	.800	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.645	.825	.805	.809	.718
	2	.718	----	.802	.789	.773	.718
	3	.742	.796	----	.718	.822	.722
	4	.749	.800	.767	----	.771	.713
	5	.745	.785	.833	.747	----	.691
	6	.733	.800	.842	.793	.631	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.033	.100	.060	.022	.009
	2	.007	----	.071	.080	.042	.025
	3	.031	.051	----	.071	.045	.027
	4	.020	.069	.082	----	.018	.036
	5	.007	.065	.071	.042	----	.040
	6	-.020	.049	.107	.080	.009	----

Subject 2

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.938	.905	.900	.927	.931
	2	.945	----	.909	.896	.922	.929
	3	.938	.929	----	.889	.907	.938
	4	.945	.936	.893	----	.889	.938
	5	.947	.931	.905	.900	----	.918
	6	.936	.942	.907	.905	.911	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.482	.407	.413	.400	.409
	2	.436	----	.442	.391	.418	.425
	3	.442	.462	----	.365	.405	.438
	4	.447	.487	.402	----	.353	.422
	5	.458	.453	.436	.385	----	.380
	6	.416	.473	.433	.391	.398	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.360	.356	.302	.371	.411
	2	.418	----	.351	.256	.396	.380
	3	.393	.345	----	.273	.380	.409
	4	.362	.373	.333	----	.318	.413
	5	.380	.385	.351	.280	----	.405
	6	.373	.367	.371	.309	.380	----

Subject 3

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.887	.880	.856	.922	.893
	2	.918	----	.885	.833	.909	.893
	3	.909	.896	----	.820	.918	.896
	4	.913	.893	.840	----	.896	.896
	5	.911	.891	.900	.858	----	.878
	6	.913	.893	.880	.853	.898	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.320	.278	.251	.369	.349
	2	.387	----	.256	.238	.351	.336
	3	.376	.258	----	.191	.389	.353
	4	.413	.216	.209	----	.382	.347
	5	.393	.291	.329	.260	----	.293
	6	.402	.280	.271	.249	.365	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.322	.305	.236	.267	.345
	2	.367	----	.256	.207	.305	.340
	3	.353	.309	----	.160	.327	.325
	4	.367	.282	.240	----	.245	.340
	5	.362	.282	.302	.231	----	.296
	6	.342	.325	.276	.242	.289	----

Subject 4

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.927	.862	.969	.902	.976
	2	.867	----	.978	.962	.851	.978
	3	.862	.929	----	.960	.907	.978
	4	.873	.929	.962	----	.898	.973
	5	.873	.860	.978	.962	----	.962
	6	.873	.929	.978	.965	.891	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.249	.302	.500	.658	.705
	2	.398	----	.500	.518	.293	.705
	3	.356	.245	----	.473	.613	.727
	4	.438	.282	.489	----	.545	.660
	5	.442	.222	.513	.536	----	.700
	6	.433	.282	.516	.542	.640	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.036	.005	.062	.058	.016
	2	.029	----	.067	.042	.016	.022
	3	.047	.009	----	.031	.045	.045
	4	.029	.013	.047	----	.047	.040
	5	.040	-.007	.085	.029	----	.029
	6	.040	.007	.042	.071	.016	----

Subject 5

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.962	.913	.929	.942	.976
	2	.958	----	.911	.938	.940	.976
	3	.965	.933	----	.909	.940	.976
	4	.965	.971	.876	----	.940	.971
	5	.962	.969	.916	.916	----	.962
	6	.965	.973	.911	.940	.933	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.451	.427	.405	.360	.398
	2	.431	----	.402	.471	.345	.391
	3	.451	.465	----	.389	.342	.393
	4	.438	.507	.333	----	.360	.402
	5	.442	.491	.362	.367	----	.378
	6	.438	.445	.400	.440	.318	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.165	.153	.122	.116	.120
	2	.136	----	.180	.116	.129	.116
	3	.147	.178	----	.129	.116	.107
	4	.147	.171	.111	----	.129	.118
	5	.149	.142	.136	.125	----	.125
	6	.129	.145	.153	.122	.127	----

Subject 6

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.849	.889	.880	.862	.931
	2	.916	----	.849	.871	.853	.922
	3	.960	.845	----	.847	.845	.916
	4	.973	.858	.873	----	.789	.920
	5	.973	.860	.889	.809	----	.880
	6	.976	.858	.893	.882	.802	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.518	.613	.725	.545	.689
	2	.711	----	.533	.638	.529	.678
	3	.847	.485	----	.580	.511	.667
	4	.891	.545	.569	----	.398	.693
	5	.882	.551	.589	.476	----	.593
	6	.869	.558	.618	.693	.353	----

Table IV (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	----	.062	.085	.053	.089	.080
	2	.069	----	.076	.071	.058	.093
Stimulus	3	.053	.082	----	.038	.080	.113
	4	.067	.080	.073	----	.065	.082
	5	.089	.069	.080	.040	----	.091
	6	.040	.080	.098	.038	.111	----

Table V

Individual Subjects' Data

Estimates of P_k obtained by subtracting the off-diagonal column entries from the diagonal column entry in Table II the stimulus set size was 4.

Subject 1

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.850	.927	.907	.860	.930
	2	.887	----	.897	.903	.843	.943
	3	.933	.860	----	.870	.870	.940
	4	.933	.867	.913	----	.837	.923
	5	.927	.853	.930	.873	----	.890
	6	.933	.867	.943	.897	.833	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.693	.813	.800	.807	.827
	2	.807	----	.760	.790	.733	.850
	3	.843	.737	----	.693	.813	.853
	4	.860	.740	.733	----	.777	.830
	5	.860	.707	.843	.727	----	.803
	6	.833	.737	.847	.743	.780	----

Table V (Cont'd)

300 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.203	.207	.083	.187	.010
	2	.187	----	.183	.103	.047	.170
	3	.213	.120	----	.050	.157	.150
	4	.207	.093	.060	----	.163	.167
	5	.223	.027	.190	.090	----	.160
	6	.010	.147	.180	.150	.203	----

Subject 2

Accuracy

Response

		1	2	3	4	5	6
Stimulus	1	----	.930	.960	.953	.967	.940
	2	.947	----	.960	.947	.937	.960
	3	.953	.927	----	.947	.963	.960
	4	.950	.933	.950	----	.960	.957
	5	.957	.930	.967	.937	----	.960
	6	.940	.933	.963	.953	.960	----

440 Ms

Response

		1	2	3	4	5	6
Stimulus	1	----	.553	.640	.587	.527	.580
	2	.670	----	.593	.570	.423	.630
	3	.683	.543	----	.520	.520	.620
	4	.677	.560	.517	----	.523	.610
	5	.643	.443	.593	.587	----	.620
	6	.583	.550	.613	.623	.517	----

Table V (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	----	.483	.517	.557	.547	.460
	2	.540	----	.497	.543	.420	.563
Stimulus	3	.527	.470	----	.517	.510	.540
	4	.550	.500	.473	----	.503	.537
	5	.547	.420	.523	.523	----	.550
	6	.470	.457	.517	.567	.553	----

Subject 3

Accuracy
Response

		1	2	3	4	5	6
	1	----	.877	.893	.920	.923	.910
	2	.947	----	.877	.910	.880	.910
Stimulus	3	.950	.883	----	.863	.927	.900
	4	.950	.863	.867	----	.930	.913
	5	.947	.873	.893	.897	----	.913
	6	.947	.873	.903	.903	.897	----

440 Ms
Response

		1	2	3	4	5	6
	1	----	.353	.420	.453	.470	.410
	2	.473	----	.370	.440	.370	.453
Stimulus	3	.457	.387	----	.273	.537	.453
	4	.490	.370	.277	----	.513	.457
	5	.483	.247	.427	.500	----	.450
	6	.400	.363	.427	.457	.460	----

Table V (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	----	.403	.407	.413	.427	.383
	2	.510	----	.383	.410	.293	.437
Stimulus	3	.517	.407	----	.190	.483	.437
	4	.530	.370	.280	----	.443	.410
	5	.483	.347	.380	.417	----	.407
	6	.447	.383	.400	.403	.400	----

Subject 4

Accuracy
Response

		1	2	3	4	5	6
	1	----	.897	.887	.973	.907	.960
	2	.933	----	.923	.967	.843	.957
Stimulus	3	.933	.873	----	.943	.910	.963
	4	.940	.897	.930	----	.897	.960
	5	.937	.840	.933	.950	----	.963
	6	.937	.893	.930	.960	.903	----

440 Ms
Response

		1	2	3	4	5	6
	1	----	.353	.567	.663	.543	.703
	2	.513	----	.673	.637	.287	.720
Stimulus	3	.533	.363	----	.600	.597	.737
	4	.557	.400	.617	----	.573	.683
	5	.557	.293	.663	.610	----	.707
	6	.517	.377	.683	.667	.587	----

Table V (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.090	.123	.187	.137	.017
	2	.130	----	.130	.143	.030	.120
	3	.150	.167	----	-.050	.167	.120
	4	.147	.143	-.010	----	.147	.127
	5	.153	-.007	.100	.140	----	.167
	6	.047	.100	.120	.150	.137	----

Subject 5

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	----	.963	.950	.957	.937	.950
	2	.967	----	.940	.963	.940	.947
	3	.973	.963	----	.923	.947	.950
	4	.970	.970	.927	----	.940	.950
	5	.970	.970	.947	.937	----	.933
	6	.970	.963	.953	.950	.920	----

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.493	.453	.587	.413	.393
	2	.487	----	.463	.587	.393	.410
	3	.487	.547	----	.420	.457	.430
	4	.470	.567	.393	----	.477	.433
	5	.473	.470	.420	.560	----	.417
	6	.420	.483	.470	.560	.407	----

Table V (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
	1	----	.257	.277	.333	.193	.153
	2	.267	----	.313	.293	.150	.190
Stimulus	3	.230	.370	----	.113	.313	.187
	4	.223	.360	.130	----	.303	.197
	5	.233	.210	.240	.333	----	.197
	6	.197	.203	.237	.347	.230	----

Subject 6

Accuracy
Response

		1	2	3	4	5	6
	1	----	.910	.917	.897	.863	.930
	2	.947	----	.900	.887	.847	.937
Stimulus	3	.973	.903	----	.847	.860	.933
	4	.973	.907	.903	----	.807	.927
	5	.973	.903	.910	.830	----	.900
	6	.967	.913	.917	.877	.843	----

440 Ms
Response

		1	2	3	4	5	6
	1	----	.687	.707	.767	.693	.800
	2	.857	----	.643	.707	.630	.817
Stimulus	3	.910	.620	----	.637	.673	.813
	4	.930	.673	.633	----	.620	.797
	5	.897	.667	.693	.657	----	.740
	6	.900	.680	.710	.700	.663	----

Table V (Cont'd)

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	----	.110	.110	.227	.237	.067
	2	.200	----	.097	.220	-.020	.253
	3	.293	.043	----	.087	.077	.250
	4	.283	.037	.067	----	.087	.277
	5	.223	.010	.093	.193	----	.230
	6	.093	.110	.140	.177	.230	----

Appendix Tables of Estimates of Mean Response Latencies for Individual Subjects. Table VI is for set size 6 and Table VII is for set size 4.

Table VI

<u>Individual Subjects' Data</u>

Mean response latencies (ms) for the 6-choice condition.

Subject 1

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	457	433	352	---	359	185	453
	2	410	452	469	581	454	---	452
	3	354	439	435	407	425	---	432
	4	289	---	426	463	458	400	457
	5	309	419	384	369	443	458	440
	6	457	436	---	---	416	451	448
	Aver.	453	449	433	456	442	450	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	425	418	401	393	460	388	423
	2	365	443	410	376	432	391	435
	3	393	334	421	412	316	---	418
	4	265	363	380	432	395	340	423
	5	495	424	381	411	427	394	424
	6	452	384	297	363	408	440	428
	Aver.	423	434	414	424	423	436	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	280	293	200	209	232	195	224
	2	221	434	207	194	277	191	234
	3	231	258	229	210	210	183	219
	4	190	225	206	250	223	175	214
	5	219	278	196	203	282	184	214
	6	219	264	199	191	255	290	225
	Aver.	227	319	207	212	248	206	

Table VI (Cont'd)

Subject 2

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	708	675	334	273	219	286	689
	2	307	702	486	264	263	276	678
	3	299	760	710	626	300	410	686
	4	274	276	433	749	424	223	715
	5	212	330	217	638	667	463	652
	6	469	---	261	455	343	719	700
	Aver.	687	696	696	736	620	694	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	602	256	256	269	240	281	440
	2	297	620	242	251	223	251	461
	3	255	267	567	334	247	204	417
	4	242	244	322	597	297	256	427
	5	261	267	231	258	499	288	399
	6	278	286	239	259	265	640	443
	Aver.	446	456	436	456	351	499	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	614	243	248	251	226	212	422
	2	290	619	248	238	227	238	413
	3	258	306	568	248	230	236	392
	4	264	244	278	649	236	235	398
	5	238	235	225	276	514	293	404
	6	251	244	230	224	245	671	441
	Aver.	428	444	408	433	333	502	

Table VI (Cont'd)

Subject 3

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	723	390	291	261	269	166	689
	2	346	794	404	367	403	359	755
	3	311	406	677	636	237	---	661
	4	372	531	541	766	368	---	729
	5	243	466	344	297	649	430	631
	6	285	309	253	355	490	729	691
	Aver.	708	770	637	719	616	721	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	551	316	275	237	270	234	398
	2	259	615	278	270	266	276	406
	3	269	297	639	325	279	275	435
	4	282	337	299	662	283	279	434
	5	276	282	268	260	552	307	419
	6	274	265	256	251	315	597	411
	Aver.	430	426	412	415	396	434	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	597	260	266	254	259	271	412
	2	274	635	284	296	290	265	430
	3	256	293	579	306	266	274	406
	4	275	319	318	659	282	262	422
	5	285	299	256	252	587	306	414
	6	265	256	259	247	306	653	426
	Aver.	433	436	391	408	393	468	

Table VI (Cont'd)

Subject 4

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	681	559	575	---	180	332	666
	2	543	636	---	270	504	---	625
	3	331	456	612	586	---	---	608
	4	---	332	533	551	443	284	548
	5	---	564	---	421	570	451	567
	6	---	302	---	196	360	487	483
	Aver.	676	629	607	547	560	485	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	661	363	400	356	318	280	497
	2	337	585	323	352	406	262	439
	3	429	380	603	396	327	258	497
	4	242	329	341	456	353	286	406
	5	265	380	264	309	419	318	395
	6	266	258	248	311	304	426	394
	Aver.	574	488	499	411	389	384	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	359	175	159	156	169	187	193
	2	159	248	135	173	171	175	178
	3	178	156	202	174	173	170	177
	4	164	238	147	319	180	195	213
	5	193	161	145	157	214	200	183
	6	194	185	150	147	161	281	183
	Aver.	217	194	159	194	179	205	

Table VI (Cont'd)

Subject 5

Accuracy
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	627	525	461	540	---	---	623
	2	576	623	393	238	117	---	615
	3	---	714	718	485	126	---	707
	4	---	104	576	625	525	575	621
	5	306	213	345	372	747	649	728
	6	---	---	387	414	443	794	785
	Aver.	626	622	705	605	741	791	

440 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	553	224	179	215	150	215	368
	2	388	487	185	180	170	224	360
	3	186	304	495	220	205	249	370
	4	234	194	240	395	159	303	339
	5	183	207	259	242	618	476	400
	6	295	332	220	209	281	710	437
	Aver.	486	388	341	277	443	654	

300 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	636	230	177	177	138	205	260
	2	271	489	167	166	142	158	257
	3	202	225	412	176	147	162	273
	4	153	168	189	354	147	228	263
	5	154	168	185	165	544	304	250
	6	155	192	185	184	184	1265	328
	Aver.	416	291	236	212	281	857	

Table VI (Cont'd)

Subject 6

Accuracy
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	481	366	261	232	275	---	477
	2	553	680	463	357	262	315	650
	3	350	448	672	484	309	278	642
	4	157	421	448	591	409	334	568
	5	288	140	346	415	611	543	591
	6	---	354	---	---	433	686	668
	Aver.	482	667	655	571	573	666	

440 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	414	415	328	287	294	338	408
	2	468	508	433	369	328	307	468
	3	346	441	496	409	378	331	458
	4	273	398	439	440	405	325	428
	5	343	367	392	410	448	387	426
	6	322	---	429	370	397	417	407
	Aver.	415	492	478	421	420	403	

300 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	268	245	172	226	173	196	214
	2	228	478	437	200	165	202	239
	3	195	277	407	214	186	198	223
	4	184	271	907	311	199	198	248
	5	189	233	178	233	249	219	225
	6	174	249	217	208	200	285	223
	Aver.	209	330	419	237	197	221	

Table VII

Individual Subjects' Data

Mean response latencies (msec) for the 4-choice stimulus condition.

Subject 1

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	440	400	443	---	365	366	437
	2	463	476	422	317	435	---	471
	3	511	381	426	427	---	339	426
	4	479	486	452	450	452	379	449
	5	288	367	389	400	454	425	446
	6	309	444	---	434	411	446	443
	Aver.	439	471	427	447	450	442	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	424	406	434	294	536	421	423
	2	418	449	386	368	411	358	436
	3	478	428	412	380	---	306	409
	4	366	302	398	424	359	348	416
	5	321	414	371	374	431	391	423
	6	400	356	272	429	365	437	431
	Aver.	423	443	408	415	425	431	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	245	228	228	205	238	211	229
	2	248	235	237	213	206	196	224
	3	242	187	238	236	178	211	220
	4	204	223	232	285	194	211	229
	5	249	243	201	225	241	194	231
	6	225	225	200	270	218	250	230
	Aver.	235	226	227	242	216	218	

Table VII (Cont'd)

Subject 2

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	705	184	281	---	303	405	690
	2	773	676	567	316	247	345	656
	3	555	742	635	479	230	438	628
	4	413	---	537	693	674	318	685
	5	---	248	---	566	635	315	631
	6	490	---	225	---	544	669	662
	Aver.	700	673	629	686	611	657	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	618	635	236	295	197	227	523
	2	237	597	264	252	209	239	447
	3	252	227	577	278	208	253	464
	4	263	203	259	571	347	296	471
	5	284	245	229	261	485	225	395
	6	256	300	239	244	253	597	479
	Aver.	509	495	465	460	365	513	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	643	246	262	258	264	203	483
	2	266	570	314	245	220	203	420
	3	228	241	544	279	231	260	423
	4	254	297	273	544	251	260	435
	5	240	235	232	266	470	220	386
	6	254	211	226	249	261	606	457
	Aver.	490	442	425	442	355	478	

Table VII (Cont'd)

Subject 3

Accuracy
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	718	345	408	293	337	370	700
	2	319	737	561	387	335	386	700
	3	---	309	737	386	268	326	704
	4	---	378	420	704	191	---	682
	5	395	317	275	499	689	---	670
	6	208	278	246	304	553	704	678
	Aver.	714	710	702	658	658	696	

440 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	612	294	261	265	291	236	444
	2	274	549	274	282	291	281	398
	3	297	253	551	283	218	266	412
	4	323	286	307	473	250	239	393
	5	251	267	248	232	504	248	398
	6	269	270	245	246	347	601	445
	Aver.	499	409	406	359	402	457	

300 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	563	273	271	271	284	231	430
	2	275	571	316	278	290	266	419
	3	292	264	530	310	269	272	410
	4	248	287	316	530	316	251	418
	5	271	298	254	281	550	306	425
	6	279	280	264	292	276	616	442
	Aver.	466	439	400	390	409	469	

Table VII (Cont'd)

Subject 4

Accuracy
Response

		1	2	3	4	5	6	Aver.
	1	604	---	448	253	310	663	594
	2	419	623	613	403	562	376	613
Stimulus	3	428	604	616	537	---	---	612
	4	---	---	379	510	405	221	507
	5	339	480	---	612	580	---	575
	6	131	300	178	352	355	476	470
	Aver.	599	613	606	508	574	475	

440 Ms
Response

			2	3	4	5	6	Aver.
	1	537	300	375	309	329	254	450
	2	364	537	353	316	358	229	423
Stimulus	3	428	406	494	314	279	257	449
	4	275	145	281	410	297	303	380
	5	335	329	306	348	436	373	400
	6	295	280	280	261	286	411	377
	Aver.	487	457	439	368	388	389	

300 Ms
Response

		1	2	3	4	5	6	Aver.
	1	259	162	194	222	158	160	195
	2	157	289	185	170	180	154	198
Stimulus	3	231	167	268	165	183	170	199
	4	156	209	153	258	173	174	196
	5	147	163	151	163	237	152	179
	6	166	157	163	151	156	262	185
	Aver.	196	200	191	192	188	188	

Table VII (Cont'd)

Subject 5

Accuracy
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	617	471	502	540	393	---	613
	2	794	651	472	---	196	363	646
	3	---	655	668	430	---	---	659
	4	163	---	409	577	656	---	571
	5	353	---	447	553	731	611	721
	6	422	365	---	332	484	719	704
	Aver.	615	648	657	567	717	716	

440 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	513	218	189	210	192	213	364
	2	283	481	216	198	198	267	376
	3	335	183	431	211	243	200	337
	4	257	204	213	391	226	201	339
	5	247	210	243	247	537	217	391
	6	223	273	219	220	222	631	413
	Aver.	426	373	323	300	386	514	

300 Ms
Response

Stimulus		1	2	3	4	5	6	Aver.
	1	458	185	168	156	144	139	251
	2	221	398	199	166	156	230	267
	3	158	269	312	164	138	241	231
	4	207	161	186	260	196	162	224
	5	223	199	223	184	448	256	292
	6	184	215	188	150	195	614	283
	Aver.	314	277	231	195	270	419	

Table VII (Cont'd)

Subject 6

Accuracy
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	475	356	266	275	---	301	471
	2	441	654	490	327	280	243	631
	3	360	358	551	394	317	304	537
	4	213	152	437	519	393	378	504
	5	288	337	393	431	555	455	538
	6	264	---	240	398	382	487	480
	Aver.	470	643	544	501	537	478	

440 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	427	355	355	316	348	376	422
	2	410	495	416	353	338	304	458
	3	336	384	460	371	334	344	433
	4	---	429	377	413	376	288	402
	5	359	369	340	396	440	413	425
	6	301	317	347	383	365	431	419
	Aver.	419	475	442	401	419	419	

300 Ms
Response

		1	2	3	4	5	6	Aver.
Stimulus	1	260	183	196	183	170	186	215
	2	197	295	187	192	202	177	208
	3	183	237	340	207	174	183	218
	4	206	218	200	252	212	205	223
	5	175	243	199	198	285	191	223
	6	214	192	214	202	188	260	230
	Aver.	217	245	248	215	218	209	

Appendix Tables for

Estimates of μ_i

Table VIII

Individual Subjects' Data.

Estimates of μi calculated from the mean response latencies of Table V and the response probabilities of Table 1 according to equation (7). The stimulus set size was 6.

Subject 1

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	453	436	463	443	451
	2	457	---	434	462	442	451
	3	459	452	---	466	443	451
	4	458	452	436	---	442	451
	5	458	452	435	467	---	450
	6	457	452	435	463	446	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	450	422	433	427	440
	2	428	---	422	435	427	440
	3	425	446	---	435	428	440
	4	426	445	426	---	430	441
	5	424	444	423	434	---	442
	6	424	444	424	435	433	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	706	319	389	546	1834
	2	1609	---	337	379	293	809
	3	481	595	---	359	437	797
	4	899	522	323	---	690	668
	5	1656	514	386	500	---	590
	6	-265	604	317	385	676	---

Table VIII (Cont'd)

Subject 2

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	702	713	753	675	725
	2	712	---	710	755	676	726
	3	715	701	---	752	681	721
	4	712	705	715	---	682	722
	5	711	706	714	750	---	726
	6	712	702	712	750	678	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	685	638	636	613	694
	2	670	---	609	660	603	683
	3	674	701	---	668	605	673
	4	672	684	626	---	626	684
	5	658	710	617	666	---	724
	6	694	687	617	659	603	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	715	644	740	676	731
	2	673	---	649	835	648	768
	3	704	716	---	793	663	730
	4	741	698	661	---	743	725
	5	726	686	655	770	---	727
	6	731	706	631	735	655	---

Table VIII (Cont'd)

Subject 3

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	802	690	776	655	730
	2	724	---	685	785	657	730
	3	728	798	---	774	657	729
	4	726	797	688	---	662	729
	5	728	799	680	774	---	735
	6	727	800	691	775	656	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	684	808	857	661	675
	2	609	---	852	874	682	682
	3	617	783	---	971	638	661
	4	584	845	961	---	643	668
	5	600	733	726	827	---	726
	6	593	757	830	856	647	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	743	693	851	797	724
	2	670	---	764	906	717	731
	3	690	753	---	1072	696	751
	4	670	784	771	---	828	732
	5	672	793	700	863	---	785
	6	701	741	742	837	731	---

Table VIII (Cont'd)

Subject 4

Accuracy
Response

		1	2	3	4	5	6
	1	---	636	617	551	572	487
	2	683	---	612	552	574	487
Stimulus	3	686	636	---	550	570	487
	4	681	636	613	---	571	488
	5	681	642	612	551	---	488
	6	681	636	612	552	573	---

440 Ms
Response

		1	2	3	4	5	6
	1	---	633	767	478	432	438
	2	704	---	629	475	439	439
Stimulus	3	724	634	---	474	438	434
	4	674	603	634	---	443	447
	5	669	659	625	476	---	435
	6	677	608	624	474	437	---

300 Ms
Response

		1	2	3	4	5	6
	1	---	494	2146	728	408	1143
	2	1069	---	341	929	1024	927
Stimulus	3	687	1772	---	1189	452	566
	4	1051	357	390	---	403	535
	5	738	-1883	283	1378	---	642
	6	735	1666	404	674	1196	---

Table VIII (Cont'd)

Subject 5

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	624	719	627	747	794
	2	627	---	720	630	749	794
	3	627	619	---	631	749	794
	4	627	624	725	---	748	795
	5	628	625	719	634	---	796
	6	627	623	720	627	750	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	550	565	518	676	721
	2	567	---	586	490	696	729
	3	567	524	---	526	694	725
	4	575	517	639	---	675	714
	5	575	526	598	526	---	728
	6	571	527	578	496	710	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	661	789	882	864	1383
	2	744	---	711	959	786	1435
	3	722	631	---	849	856	1541
	4	731	681	992	---	783	1402
	5	723	785	854	904	---	1334
	6	811	754	777	862	771	---

Table VIII (Cont'd)

Subject 6

Accuracy
Response

		1	2	3	4	5	6
	1	---	685	674	592	613	686
	2	477	---	683	594	617	690
Stimulus	3	483	685	---	595	619	693
	4	482	681	677	---	631	690
	5	482	681	674	607	---	694
	6	481	682	672	591	626	---

440 Ms
Response

		1	2	3	4	5	6
	1	---	515	499	443	453	419
	2	400	---	507	451	456	421
Stimulus	3	418	518	---	449	455	422
	4	415	511	502	---	466	419
	5	415	510	503	457	---	422
	6	417	508	497	444	478	---

300 Ms
Response

		1	2	3	4	5	6
	1	---	703	493	506	492	534
	2	389	---	391	474	708	473
Stimulus	3	574	576	---	664	478	431
	4	531	588	119	---	487	520
	5	436	668	508	577	---	440
	6	824	599	441	688	364	---

Table IX

Individual Subjects' Data

Estimates of μi calculated from the mean response latencies of Table VI and the response probabilities of Table II. The stimulus set size was 4.

Subject 1

Accuracy

		Response					
		1	2	3	4	5	6
Stimulus	1	---	477	426	450	455	447
	2	438	---	426	451	454	446
	3	439	477	---	451	454	446
	4	439	476	425	---	454	447
	5	442	478	427	452	---	447
	6	440	476	426	450	455	---

440 Ms

		Response					
		1	2	3	4	5	6
Stimulus	1	---	452	411	426	430	438
	2	424	---	415	426	434	438
	3	423	449	---	432	431	438
	4	424	450	414	---	435	440
	5	425	451	412	430	---	440
	6	425	450	413	424	434	---

300 Ms

		Response					
		1	2	3	4	5	6
Stimulus	1	---	237	242	387	243	1312
	2	243	---	238	345	426	286
	3	248	289	---	422	296	285
	4	280	255	257	---	279	278
	5	243	167	257	352	---	294
	6	1012	243	261	289	251	---

Table IX (Cont'd)

Subject 2

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	678	637	693	638	675
	2	705	---	635	695	651	670
	3	706	675	---	694	640	670
	4	707	676	636	---	634	671
	5	705	677	635	695	---	670
	6	709	676	636	693	636	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	595	588	603	534	644
	2	642	---	612	618	611	610
	3	634	629	---	647	536	616
	4	637	618	665	---	509	618
	5	654	713	616	607	---	617
	6	698	619	603	587	530	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	603	586	572	503	720
	2	687	---	588	581	597	625
	3	703	614	---	592	528	638
	4	681	588	613	---	527	640
	5	685	660	585	590	---	634
	6	753	630	591	567	501	---

Table IX (Cont'd)

Subject 3

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	741	743	708	693	705
	2	719	---	744	711	710	705
	3	718	738	---	728	692	710
	4	718	746	753	---	691	704
	5	719	743	746	711	---	704
	6	720	744	741	715	694	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	607	604	526	552	695
	2	640	---	646	529	623	645
	3	651	584	---	678	525	647
	4	625	594	745	---	535	648
	5	634	762	601	506	---	653
	6	709	602	601	529	544	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	613	581	595	617	717
	2	587	---	588	596	763	654
	3	582	612	---	909	580	653
	4	577	640	689	---	598	682
	5	605	661	608	590	---	675
	6	631	630	588	597	642	---

Table IX (Cont'd)

Subject 4

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	623	625	511	581	475
	2	605	---	616	511	582	476
	3	605	623	---	509	580	476
	4	604	623	617	---	583	477
	5	605	632	616	506	---	476
	6	606	624	618	513	582	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	572	525	424	454	420
	2	559	---	502	428	531	417
	3	546	552	---	435	447	412
	4	547	543	527	---	451	420
	5	545	617	508	425	---	413
	6	565	557	503	430	449	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	481	342	281	319	1724
	2	342	---	342	359	705	385
	3	275	332	---	-407	273	366
	4	322	335	-2672	---	295	351
	5	320	-4104	440	372	---	321
	6	638	455	378	370	321	---

Table IX (Cont'd)

Subject 5

Accuracy
Response

		1	2	3	4	5	6
	1	---	652	669	577	734	719
	2	615	---	671	577	735	720
Stimulus	3	617	651	---	583	731	719
	4	618	651	676	---	731	719
	5	618	651	670	577	---	721
	6	617	653	668	580	738	---

440 Ms
Response

		1	2	3	4	5	6
	1	---	538	485	424	626	695
	2	529	---	473	426	646	669
Stimulus	3	525	510	---	508	578	654
	4	540	498	520	---	565	651
	5	539	557	491	425	---	667
	6	582	532	469	432	625	---

300 Ms
Response

		1	2	3	4	5	6
	1	---	528	383	314	704	831
	2	491	---	348	328	850	682
Stimulus	3	554	413	---	590	491	687
	4	548	433	586	---	492	675
	5	529	592	376	299	---	663
	6	607	588	404	310	587	---

Table IX (Cont'd)

Subject 6

Accuracy
Response

		1	2	3	4	5	6
Stimulus	1	---	655	552	520	555	490
	2	476	---	552	522	561	489
	3	475	657	---	526	556	489
	4	476	658	553	---	567	489
	5	475	657	553	526	---	489
	6	477	654	552	522	559	---

440 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	496	462	414	441	434
	2	428	---	465	419	452	434
	3	429	508	---	422	445	434
	4	427	496	471	---	448	438
	5	429	500	464	416	---	434
	6	431	498	461	416	444	---

300 Ms
Response

		1	2	3	4	5	6
Stimulus	1	---	326	406	287	306	657
	2	324	---	441	285	-961	316
	3	289	426	---	386	578	314
	4	283	513	537	---	448	289
	5	329	972	441	293	---	318
	6	412	323	358	299	306	---

Appendix Tables for

The 2 Stimulus Set

Size Condition

Table X

Individual Subjects' Data

Estimate of probability correct, probability of error response i given stimulus j, mean correct latency, mean error latency for response i given stimulus j, probability of entering the response selection state and mean latency for response i from the selection state. These estimates are for the 2 stimulus set condition.

Subject 1

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.973	.013	385	359	.960	385
2	5	.947	.007	381	345	.940	381
3	4	.947	.073	345	321	.873	347
4	3	.927	.053	348	288	.873	352
5	2	.993	.053	374	446	.940	370
6	1	.987	.027	388	289	.960	391

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.980	.000	404	---	.980	404
2	5	.967	.027	394	360	.940	395
3	4	.960	.047	354	310	.913	356
4	3	.953	.040	358	301	.913	361
5	2	.973	.033	371	368	.940	371
6	1	1.000	.020	389	400	.98	389

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.473	.400	246	247	.073	241
2	5	.680	.533	226	223	.147	237
3	4	.560	.467	236	208	.093	374
4	3	.533	.440	241	210	.093	384
5	2	.467	.320	233	228	.147	245
6	1	.600	.527	273	243	.073	489

Table X (Cont'd)

Subject 2

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.987	.033	552	267	.953	562
2	5	.980	.033	573	327	.947	582
3	4	.953	.033	555	309	.920	564
4	3	.967	.047	531	321	.920	541
5	2	.967	.020	517	248	.947	522
6	1	.967	.013	533	243	.953	537

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.787	.267	496	262	.520	616
2	5	.873	.133	493	243	.740	538
3	4	.747	.180	410	243	.567	464
4	3	.820	.253	421	255	.567	495
5	2	.867	.127	400	241	.740	428
6	1	.733	.213	460	254	.520	544

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.780	.293	444	228	.487	575
2	5	.800	.260	439	214	.540	548
3	4	.760	.333	381	212	.427	513
4	3	.667	.240	396	222	.427	495
5	2	.740	.200	386	224	.540	446
6	1	.707	.220	393	236	.487	464

Table X (Cont'd)

Subject 3

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.940	.053	547	287	.887	563
2	5	.893	.113	479	283	.780	507
3	4	.880	.147	472	282	.733	511
4	3	.853	.120	460	265	.733	492
5	2	.887	.107	451	296	.780	472
6	1	.947	.060	514	250	.887	531

400 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.660	.260	437	247	.400	560
2	5	.653	.220	408	297	.433	465
3	4	.493	.313	385	265	.180	595
4	3	.687	.507	324	266	.180	486
5	2	.780	.347	366	268	.433	445
6	1	.740	.340	359	249	.400	452

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.620	.260	396	259	.360	494
2	5	.720	.233	427	282	.487	497
3	4	.553	.313	332	261	.240	424
4	3	.687	.447	380	271	.240	582
5	2	.767	.280	367	269	.487	424
6	1	.740	.380	361	227	.360	503

Table X (Cont'd)

Subject 4

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.987	.007	458	316	.980	459
2	5	.960	.053	488	359	.907	496
3	4	.940	.047	428	308	.893	434
4	3	.953	.060	383	307	.893	388
5	2	.947	.040	459	308	.907	466
6	1	.993	.013	391	308	.980	392

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.787	.093	387	237	.693	407
2	5	.747	.213	396	271	.533	446
3	4	.767	.167	336	250	.600	360
4	3	.833	.233	338	281	.600	360
5	2	.787	.253	369	305	.533	399
6	1	.907	.213	358	284	.693	381

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μ_i
1	6	.500	.407	225	157	.093	520
2	5	.480	.413	220	164	.067	566
3	4	.493	.413	276	196	.080	693
4	3	.587	.507	245	187	.080	611
5	2	.587	.520	202	183	.067	353
6	1	.593	.500	200	151	.093	462

Table X (Cont'd)

Subject 5

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.980	.000	561	---	.980	561
2	5	.993	.007	474	295	.987	475
3	4	.933	.007	626	240	.927	629
4	3	.993	.067	460	422	.927	462
5	2	.993	.007	497	286	.987	499
6	1	1.000	.020	544	279	.980	549

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.767	.160	435	226	.607	490
2	5	.813	.087	396	254	.727	412
3	4	.780	.167	439	261	.613	488
4	3	.833	.220	341	219	.613	385
5	2	.913	.187	363	189	.727	408
6	1	.840	.233	391	247	.607	446

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.713	.327	384	197	.387	542
2	5	.693	.300	314	205	.393	397
3	4	.680	.347	332	212	.333	457
4	3	.653	.320	304	199	.333	404
5	2	.700	.307	326	176	.393	444
6	1	.673	.287	418	193	.387	585

Table X (Cont'd)

Subject 6

Accuracy

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.980	.013	447	314	.967	449
2	5	.973	.027	427	286	.947	431
3	4	.820	.067	421	283	.753	433
4	3	.933	.180	402	299	.753	426
5	2	.973	.027	408	239	.947	412
6	1	.987	.020	417	253	.967	420

440 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.853	.027	445	327	.827	449
2	5	.860	.040	419	291	.820	425
3	4	.693	.067	361	249	.627	372
4	3	.933	.307	347	261	.627	390
5	2	.960	.140	343	281	.820	353
6	1	.973	.147	379	290	.827	394

300 Ms

i	j	Pc_i	Pe_{ji}	Mc_i	Me_{ji}	P_k	μi
1	6	.473	.380	248	171	.093	561
2	5	.447	.347	281	180	.100	630
3	4	.400	.247	354	231	.153	552
4	3	.753	.600	283	200	.153	606
5	2	.653	.553	242	186	.100	552
6	1	.620	.527	212	181	.093	386

Appendix Tables for

Reaction Time Frequency

Distributions

Table XI

Reaction time frequency distributions for the 6 stimulus set condition were obtained for correct (C) and error (E) responses for each stimulus. The distributions were grouped in 25 ms intervals from 0 to 1000 ms. All response times over 1000 ms were included in the 975-1000 ms interval.

Table XI

Accuracy
Stimulus

	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	1	0	0	0	0	0	0
100	0	0	0	1	1	0	0	0	0	0	1	0
	0	0	0	3	0	1	1	1	0	1	0	1
	2	3	1	1	0	6	0	4	1	1	0	4
	0	4	0	8	1	3	2	5	1	5	1	3
200	0	8	1	4	6	3	3	7	2	13	1	5
	1	9	0	4	2	9	3	8	4	7	1	6
	0	9	1	8	1	5	5	5	1	6	0	6
	3	8	1	10	2	13	3	11	5	13	2	4
300	4	10	1	11	2	12	1	6	4	9	0	10
	5	9	3	14	8	5	9	13	9	7	3	12
	12	5	2	9	8	16	15	7	15	13	9	12
	33	10	27	12	28	8	31	14	25	10	32	16
400	132	19	62	14	82	14	64	26	80	19	68	10
	155	12	135	21	149	16	173	33	150	19	225	20
	159	13	143	13	151	13	159	31	198	20	269	20
	128	6	89	10	88	7	137	24	131	14	248	11
500	101	4	97	10	107	7	142	7	113	9	167	4
	133	1	131	10	111	8	158	8	136	8	154	1
	162	3	176	2	148	4	176	10	145	9	129	1
	155	7	182	6	154	6	134	4	139	10	134	2
600	159	5	154	5	170	2	132	5	147	3	89	1
	163	9	169	3	149	5	128	3	140	5	107	3
	156	6	143	3	133	12	102	6	84	6	88	2
	115	4	120	3	110	4	109	1	111	4	80	1
700	116	4	90	3	117	2	75	5	79	4	85	1
	119	2	104	1	100	2	84	3	93	6	63	0
	69	0	74	1	85	3	58	2	72	2	70	2
	63	0	85	1	65	1	42	0	78	3	44	0
800	50	3	62	1	55	4	54	0	58	0	47	0
	39	1	50	0	48	0	52	0	56	0	51	1
	40	1	67	1	53	3	44	3	52	1	37	1
	29	0	36	1	47	2	40	2	46	3	30	1
900	28	1	41	3	41	5	32	4	40	0	24	2
	22	2	31	2	34	0	31	0	28	0	37	0
	28	1	40	0	17	2	21	0	20	0	32	0
	21	0	22	1	17	0	14	1	21	0	31	0
1000	117	3	159	1	200	7	200	6	180	5	177	1
Total	2519	182	2499	201	2490	211	2434	265	2464	235	2536	164

Table XI (Cont'd)

440 Ms

	Stimulus 1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	1	0	1	2	0	0	0
	0	8	0	5	0	3	2	3	1	3	1	4
100	2	15	0	18	0	14	7	12	5	18	1	19
	0	41	4	34	6	34	13	21	8	17	2	37
	6	51	6	51	10	35	23	29	9	52	7	41
	7	72	10	60	14	64	21	45	18	57	3	57
200	8	69	17	85	14	57	23	53	20	67	12	84
	17	107	10	95	20	90	26	94	39	96	13	86
	21	92	20	93	23	107	27	88	24	80	19	111
	13	91	16	86	27	90	33	86	27	76	19	109
300	16	81	23	85	23	75	33	100	43	88	25	85
	22	68	13	84	22	76	52	78	50	71	20	79
	52	70	30	79	38	79	63	75	66	60	60	76
	133	58	55	86	72	79	105	75	120	85	122	78
400	205	72	124	90	142	74	184	71	175	88	213	58
	224	68	177	91	191	79	257	68	244	66	243	53
	145	45	128	67	156	47	172	45	144	32	170	36
	76	27	90	50	108	43	97	28	88	27	97	25
500	45	12	91	42	79	32	48	18	62	16	37	4
	62	7	69	13	53	11	51	16	46	12	51	8
	45	8	62	9	55	20	44	7	43	6	35	9
	35	3	51	7	34	7	34	5	29	4	28	3
600	43	4	59	4	34	2	44	7	39	8	38	11
	56	3	42	4	42	6	32	4	37	4	41	1
	47	3	37	4	37	2	21	4	32	2	32	5
	40	4	37	1	32	1	28	4	33	3	32	3
700	18	3	21	1	37	2	20	2	25	1	27	2
	35	2	17	2	26	3	19	1	15	1	26	1
	23	1	31	3	23	2	12	2	13	0	21	1
	21	3	20	1	31	1	8	0	25	0	18	0
800	16	3	20	2	17	0	9	1	18	3	20	2
	26	1	19	1	25	1	10	0	24	1	9	0
	20	0	18	0	27	2	15	1	10	1	19	1
	16	1	13	1	15	0	19	0	12	0	12	0
900	15	0	18	3	20	0	8	0	12	0	8	0
	14	0	13	1	16	2	15	0	13	1	15	0
	9	0	4	1	15	0	8	0	11	1	19	0
	12	0	14	0	7	1	8	0	8	1	4	0
1000	61	1	60	3	65	2	64	0	57	3	88	5
Total	1606	1094	1439	1262	1556	1144	1655	1044	1647	1051	1607	1094

Table XI (Cont'd)

	300 Ms Stimulus											
	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	2	32	2	33	5	20	7	35	14	27	5	37
100	16	144	10	142	25	117	36	106	41	108	17	123
	35	225	23	227	42	208	42	204	53	213	22	235
	26	252	32	256	53	232	56	242	72	210	32	266
	43	270	26	246	60	226	68	207	53	227	34	260
200	37	244	27	234	77	227	47	227	53	202	27	228
	27	163	20	222	62	176	41	201	50	204	20	185
	21	166	19	151	40	146	34	147	39	135	19	162
	12	121	10	131	35	110	32	119	29	138	31	124
300	22	90	15	97	26	99	28	103	28	84	14	94
	10	69	14	61	26	69	14	61	24	55	11	78
	15	43	17	59	15	42	16	46	21	42	8	44
	14	28	9	31	24	24	16	36	9	28	16	30
400	13	22	15	29	15	24	16	21	22	24	20	20
	17	13	13	32	13	16	15	22	22	15	16	8
	19	13	11	14	13	11	9	16	18	10	14	15
	19	5	18	8	19	10	19	15	13	10	22	10
500	19	5	20	7	18	7	13	6	18	5	18	10
	22	4	26	5	23	2	18	5	21	8	13	6
	30	6	24	1	24	4	20	5	27	4	22	9
	29	1	30	5	26	3	20	6	22	4	24	4
600	28	4	17	4	23	2	16	3	26	2	26	1
	32	1	32	2	19	4	20	4	30	4	36	1
	32	1	24	1	24	2	16	7	18	2	19	2
	23	0	20	2	11	1	20	2	13	3	24	3
700	28	2	13	1	8	1	15	4	13	3	23	1
	28	1	16	4	18	2	23	1	11	3	13	3
	15	3	17	4	12	0	8	1	10	1	20	3
	15	2	12	1	15	2	10	1	15	1	15	1
800	14	1	12	0	9	3	9	2	16	1	16	0
	3	1	14	0	10	3	8	1	14	1	12	0
	11	3	14	0	15	3	18	0	14	0	2	0
	10	2	10	1	8	2	13	0	13	2	7	0
900	5	0	10	1	13	1	3	0	9	1	12	1
	8	0	11	0	7	0	10	0	10	0	12	0
	6	0	11	0	6	1	9	0	8	0	11	2
	6	3	14	0	10	0	7	0	11	1	4	1
1000	46	1	54	6	44	7	67	5	41	0	72	4
Total	758	1941	682	2018	893	1807	839	1861	921	1778	729	1971

Table XII

Reaction time frequency distributions for the 4 stimulus set condition were obtained for correct (C) and error (E) responses for each stimulus. The distributions were grouped in 25 ms intervals from 0 to 1000 ms. All response times over 1000 ms were included in the 975-1000 ms interval.

Table XII (Cont'd)

Accuracy
Stimulus

	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	1	0	0	0	0
	0	1	0	1	0	2	0	2	1	0	1	2
	2	0	0	2	1	0	0	1	1	1	0	3
	1	3	2	2	1	2	1	3	0	1	0	2
200	0	3	0	5	0	4	3	4	1	2	0	5
	1	0	0	5	1	5	4	7	1	3	1	4
	0	4	2	2	2	3	3	2	0	3	0	5
	2	6	2	8	1	6	1	1	3	4	3	2
300	5	5	3	6	4	3	4	2	5	6	2	5
	4	5	1	10	5	8	7	7	8	7	10	5
	18	6	12	8	12	4	13	6	11	9	11	7
	48	10	19	11	48	8	40	4	23	11	28	6
400	98	5	49	13	82	14	82	8	57	13	79	8
	133	8	75	18	88	5	144	10	110	15	169	11
	115	2	76	11	99	5	139	8	140	21	193	8
	94	4	93	11	99	6	146	6	121	13	146	4
500	89	1	93	8	80	5	136	9	126	8	106	5
	113	3	92	5	103	6	121	5	85	1	106	0
	120	2	121	4	144	5	126	4	122	4	84	1
	105	2	116	4	124	2	102	1	113	4	89	2
600	111	2	101	6	118	2	92	2	118	2	78	0
	107	0	101	5	102	2	77	6	82	4	87	3
	74	0	107	0	73	1	65	2	54	2	75	0
	73	1	75	0	83	5	41	1	51	4	67	1
700	53	0	55	4	55	2	38	1	43	2	35	1
	55	3	53	1	55	1	40	1	41	1	34	0
	37	0	35	0	36	1	34	1	33	1	35	1
	19	0	48	1	18	3	28	0	35	0	31	0
800	16	1	42	0	29	2	18	4	23	0	18	0
	24	0	28	1	28	0	19	1	23	0	20	0
	24	0	27	0	13	0	32	0	35	1	16	0
	22	1	28	0	18	0	12	0	21	1	19	0
900	18	0	15	1	17	0	12	0	15	0	20	1
	18	0	10	0	21	0	12	0	9	0	19	4
	11	0	11	0	15	0	14	0	20	1	10	0
	12	0	19	2	13	0	10	0	15	0	17	0
1000	99	0	130	4	100	0	74	0	104	5	94	1
Total	1721	79	1641	159	1688	112	1690	110	1650	150	1703	97

Table XII (Cont'd)

440 Ms
Stimulus

	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	1	0	0	0	0	0	0
	0	1	0	3	1	3	1	2	1	2	0	4
100	2	12	3	13	3	10	1	8	7	8	2	13
	1	24	7	14	6	23	14	15	15	19	2	25
	3	22	7	29	3	23	16	13	8	17	6	24
	7	38	8	36	10	35	17	35	18	29	5	38
200	10	47	12	55	13	36	27	46	20	58	7	33
	7	48	12	55	19	61	30	38	17	53	11	53
	14	53	18	68	16	57	27	47	24	55	18	65
	13	59	17	52	16	52	29	58	16	57	19	57
300	23	51	19	55	32	43	40	40	18	44	17	55
	21	38	18	60	27	41	43	29	28	38	35	50
	41	35	36	57	51	43	65	36	51	54	55	42
	83	37	51	62	84	33	106	31	76	55	82	28
400	174	26	87	56	134	46	157	38	126	49	160	31
	126	27	108	56	148	40	182	35	166	44	150	27
	97	14	89	28	108	17	107	18	116	27	127	11
	82	8	78	21	88	10	56	10	67	7	58	5
500	48	6	59	11	60	5	45	5	56	6	45	2
	40	5	34	6	51	8	33	2	35	2	37	3
	54	1	44	4	42	3	30	7	33	5	30	2
	47	0	36	5	34	1	33	4	27	3	33	4
600	39	0	28	5	19	0	30	0	24	1	34	3
	51	1	32	3	27	2	23	2	31	0	32	1
	27	7	24	2	22	2	22	0	21	1	43	0
	23	2	24	1	19	0	18	2	18	2	18	0
700	26	0	16	0	17	1	16	1	20	1	39	2
	23	1	18	0	19	2	12	0	17	1	21	0
	23	0	18	1	12	1	13	0	9	0	14	0
	18	0	10	0	19	0	6	0	7	2	4	1
800	11	0	11	0	14	0	7	0	13	0	7	1
	13	0	16	0	10	1	7	1	12	0	10	0
	7	0	12	1	9	0	7	1	6	0	11	0
	7	0	9	0	7	0	6	0	6	0	9	0
900	11	0	13	0	11	1	4	0	7	0	11	0
	5	0	8	0	4	0	2	0	2	0	4	0
	9	0	9	1	6	0	3	0	2	0	6	0
	7	0	5	0	5	0	5	0	5	0	5	2
1000	43	1	44	0	33	0	35	1	35	0	50	1
Total	1236	564	1040	760	1199	601	1275	525	1160	640	1217	583

Table XII (Cont'd)

300 Ms

	Stimulus 1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	2	0	0	0	0	0	1
	3	14	1	17	3	21	8	8	5	5	6	10
100	17	69	17	67	17	67	25	63	23	64	18	58
	47	122	21	114	35	124	47	115	44	110	33	118
	42	132	41	142	30	147	49	108	48	127	47	146
	53	135	40	172	40	143	51	133	54	129	26	138
200	39	128	40	141	56	134	55	129	35	129	34	136
	30	120	30	123	35	114	41	123	46	154	35	119
	29	93	34	113	32	105	28	106	40	96	28	97
	25	77	23	89	31	88	41	95	32	81	20	100
300	21	50	12	54	23	44	22	45	16	55	19	61
	23	42	12	38	20	45	19	27	23	32	14	42
	13	22	14	30	20	17	19	19	7	30	19	23
	16	19	12	21	12	16	18	12	13	17	15	15
400	20	11	10	10	8	16	23	17	17	16	17	16
	15	4	12	6	15	13	18	7	14	7	19	11
	15	3	14	5	17	9	17	10	14	4	12	4
	16	1	16	10	14	2	25	6	21	3	14	3
500	18	6	19	8	21	10	13	8	12	2	18	2
	14	0	19	6	20	1	14	2	23	4	17	6
	20	1	19	5	22	5	23	5	28	3	16	2
	27	2	23	4	25	2	23	3	22	3	20	0
600	32	0	16	1	16	1	20	4	13	1	30	0
	28	0	19	1	17	2	14	2	25	1	22	2
	23	0	17	4	21	0	16	0	16	2	23	0
	21	1	12	1	19	3	9	2	16	1	13	1
700	18	1	17	1	12	1	8	2	9	2	6	2
	20	1	8	0	10	1	4	2	13	2	17	1
	6	0	10	2	12	0	12	2	9	0	12	1
	10	0	8	0	6	1	7	0	5	0	13	1
800	5	1	4	0	8	1	7	1	8	2	6	0
	12	0	5	1	7	0	5	0	8	0	11	1
	7	0	6	2	5	2	11	0	7	0	6	0
	3	0	3	1	5	0	5	0	6	0	9	0
900	8	0	4	0	2	1	5	1	5	1	13	2
	6	0	8	0	1	1	3	1	1	0	4	0
	6	0	6	1	1	0	5	0	3	0	5	1
	2	0	5	0	1	0	5	0	3	0	3	0
1000	34	1	32	1	28	4	25	2	29	4	38	2
Total	744	1056	609	1191	657	1143	740	1060	713	1087	678	1122

Table XIII

Reaction time frequency distributions for the 2 stimulus set condition were obtained for correct (C) and error (E) responses for each stimulus. The distributions were grouped in 25 ms intervals from 0 to 1000 ms. All response times over 1000 ms were included in the 975-1000 ms interval.

Table XIII (Cont'd)

Accuracy
Stimulus

	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	0	0	0
	2	0	0	1	0	0	2	1	1	0	0	0
	2	2	0	1	2	0	2	0	0	0	0	1
200	1	2	0	3	2	2	3	2	1	2	1	1
	3	3	4	0	7	7	7	5	2	2	4	1
	4	3	5	5	8	9	8	7	2	2	3	2
	4	2	5	3	16	14	16	5	9	7	6	2
300	3	2	10	6	14	11	22	11	12	6	17	2
	14	5	32	3	57	11	57	8	36	4	32	3
	49	1	42	3	84	12	111	9	65	3	79	2
	72	2	88	4	88	2	97	5	95	3	106	1
400	96	1	97	4	73	2	98	0	119	1	124	1
	92	0	95	3	55	4	79	1	108	0	95	1
	95	0	73	0	59	0	52	0	86	0	73	1
	81	0	60	0	49	1	48	0	61	0	61	0
500	53	0	58	0	46	0	43	0	63	0	43	0
	43	0	45	0	43	1	39	0	43	2	46	0
	40	0	63	1	48	1	38	1	28	0	42	0
	43	0	39	0	27	0	20	1	22	0	22	0
600	28	0	32	0	26	0	23	0	19	0	15	0
	27	0	26	0	21	0	13	0	15	0	22	0
	21	0	16	0	9	0	9	0	11	0	18	0
	13	0	17	0	11	0	9	0	11	0	9	0
700	13	0	4	0	7	0	13	0	11	0	8	0
	8	0	6	0	6	0	6	0	3	0	5	0
	8	0	3	0	6	2	6	0	5	0	3	0
	1	0	4	0	3	0	2	0	3	0	5	0
800	8	0	5	0	5	0	4	0	4	0	5	0
	5	0	8	0	3	0	0	0	10	0	2	0
	2	0	6	0	5	0	2	0	4	0	4	0
	11	0	3	0	5	0	1	0	1	0	1	0
900	7	0	3	0	1	0	2	0	0	0	1	0
	4	0	2	1	3	0	0	0	0	0	4	0
	3	0	2	0	2	0	1	0	2	0	2	0
	4	0	1	0	3	0	1	0	2	0	3	0
1000	17	0	8	0	27	0	9	0	9	0	21	0
Total	877	23	862	38	821	79	844	56	864	36	882	18

Table XIII (Cont'd)

440 Ms
Stimulus

	1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	0	0	0	0	0
100	4	1	0	2	1	1	1	0	2	0	4	2
	2	4	1	5	0	5	4	0	2	2	5	4
	2	9	3	4	2	5	8	2	5	3	7	3
	11	14	2	8	8	18	12	6	8	3	11	10
200	16	10	6	12	9	19	18	13	11	7	16	9
	19	18	10	19	18	21	25	22	17	10	18	20
	23	24	16	17	22	26	26	26	24	15	21	15
	18	23	18	20	28	35	46	20	39	17	39	20
300	29	28	40	29	49	34	72	14	57	13	44	17
	33	19	44	22	77	41	99	15	87	11	57	4
	53	9	60	12	101	15	127	13	111	10	95	10
	100	5	73	2	93	2	107	7	119	9	128	3
400	89	0	136	3	78	7	54	0	83	4	93	0
	82	1	85	3	30	2	42	2	77	1	56	0
	48	2	44	0	24	0	9	1	35	0	27	0
	30	2	38	0	18	1	24	0	21	0	23	1
500	23	1	30	2	19	0	11	0	21	1	12	0
	18	0	19	1	12	1	12	0	13	0	14	1
	11	2	21	0	8	0	5	0	9	0	14	1
	8	0	15	0	9	0	4	0	7	1	13	0
600	11	0	15	1	8	0	7	0	5	0	9	0
	12	1	8	0	6	0	10	0	9	1	12	0
	9	0	3	0	6	1	8	0	4	0	10	0
	9	0	6	0	7	0	8	0	3	0	8	0
700	5	0	4	0	9	0	1	0	4	0	9	0
	8	0	5	0	4	0	3	0	7	0	7	0
	6	1	4	0	5	0	2	0	3	0	3	0
	3	0	4	1	3	0	0	0	0	0	2	0
800	3	0	6	0	2	0	1	0	1	0	4	1
	6	0	3	0	3	0	1	0	2	0	5	0
	2	0	3	0	0	0	2	0	2	0	4	0
	2	0	0	0	0	0	1	0	2	0	1	0
900	2	1	3	0	1	0	1	0	0	0	1	0
	1	0	1	0	2	0	2	0	0	0	0	0
	2	0	2	0	1	0	0	0	0	0	0	0
	3	0	0	0	0	0	2	0	1	0	0	0
1000	22	0	8	0	3	0	4	0	1	0	7	0
Total	725	175	737	163	666	234	759	141	792	108	779	121

Table XIII (Cont'd)

300 Ms

	Stimulus 1		2		3		4		5		6	
	C	E	C	E	C	E	C	E	C	E	C	E
	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	2	8	0	1	1	4	6	3	2	2
100	12	20	15	16	6	8	12	7	16	11	16	11
	26	42	23	33	18	30	22	12	30	27	31	27
	31	46	34	32	24	36	30	29	36	37	45	35
	46	40	38	45	34	52	40	36	39	31	43	40
200	43	49	50	39	43	55	58	53	51	45	45	44
	40	38	44	39	53	51	53	44	43	42	50	42
	41	42	36	37	47	43	41	38	38	37	45	33
	31	30	31	28	39	28	43	37	36	30	33	35
300	30	25	30	13	24	36	45	23	28	16	31	15
	25	8	26	14	37	12	35	16	34	17	27	8
	17	9	24	5	32	14	37	11	26	6	29	4
	17	4	31	7	26	6	27	3	29	2	30	3
400	21	0	18	3	17	5	13	2	40	1	18	2
	14	1	21	0	14	2	19	1	30	1	17	3
	13	0	19	0	14	2	21	0	16	2	11	1
	17	1	19	1	6	0	7	0	13	1	16	0
500	14	1	23	1	4	0	11	0	15	1	12	1
	9	1	14	3	13	1	9	0	17	0	18	1
	17	1	15	0	11	1	11	0	8	2	8	1
	10	1	10	1	7	0	6	0	6	1	4	0
600	4	0	7	0	4	0	3	0	3	0	10	0
	8	0	4	0	9	0	4	0	6	0	3	0
	5	1	8	0	5	0	6	0	0	0	5	0
	5	2	4	0	6	0	3	0	3	0	3	1
700	3	0	3	1	5	0	5	0	4	0	6	0
	3	0	2	0	2	0	1	0	2	0	4	0
	1	0	2	0	2	0	2	0	2	0	3	0
	1	1	2	0	1	0	1	0	0	0	5	0
800	3	0	2	0	0	0	0	0	2	0	4	0
	0	0	3	0	0	0	3	0	1	0	1	0
	2	0	0	0	2	0	1	0	0	0	1	0
	1	0	0	0	2	0	0	0	2	0	3	0
900	7	0	0	1	0	0	2	0	1	0	0	1
	3	0	0	0	0	0	1	1	1	0	2	0
	3	0	1	0	1	0	0	1	0	0	0	0
	1	0	2	0	1	0	0	0	1	0	1	0
1000	10	0	10	0	8	0	9	0	2	0	8	0
Total	534	366	573	327	517	383	582	318	587	313	590	310