FIXED AND RANDOM FOREPERIOD EFFECTS ON TACHISTOSCOPIC RECOGNITION

THE EFFECTS OF FIXED AND RANDOM FOREPERIODS ON THE TACHISTOSCOPIC RECOGNITION OF SIMPLE STIMULI

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ABSTRACT

Two experiments, involving 10 subjects, were performed to determine the effects upon tachistoscopic recognition performance of the foreperiod variables of length, variability and presentation order. The results showed that whether the foreperiods were fixed or random, recognition performance was a monotonically decreasing function of the length of foreperiod. However, performance under the fixed foreperiods was found to be superior to that obtained under random foreperiod sets having the same mean length. It was also found that prior practice under a fixed foreperiod condition influenced the manner in which a subject subsequently performed under the random foreperiod condition. These results were discussed in terms of possible attentive strategies a subject might develop when exposed to these various foreperiod variables.

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CHAPTER ONE

INTRODUCTION

This thesis reports two experiments concerned with the effects of fixed and random foreperiods, defined as the temporal interval between the termination of a warning signal and the presentation of a stimulus, on the tachistoscopic recognition of simple stimuli. Of central concern are the attentive strategies that subjects develop when exposed to various arrangements of the foreperiod conditions.

The first experiment was designed to investigate the effects upon recognition performance of each of the foreperiod variables of length, variability, and presentation order; that is, whether random foreperiods were preceded or followed by fixed foreperiods. The results showed that, regardless of whether the foreperiod was fixed or random, the number of correct identifications of the test stimuli was a function of the absolute length of the foreperiod. The shorter the foreperiod, the better the recognition scores. However, performance under the fixed foreperiods was found to be superior to that obtained under those foreperiods in the random condition having the same mean length. Probably the most interesting finding was that what was learned while performing under the fixed foreperiods, influenced the manner in which a subject subsequently performed under the random conditions. When this was the sequence, the subject did best on those median foreperiods in the random set which were close to the length of the foreperiod of the preceding fixed condition, and performance became progressively poorer as the foreperiods became longer or shorter than these median values.

The second experiment was a probe study in which subjects were first given extensive practice on a fixed four second foreperiod, and later as they continued to perform with this foreperiod, shorter ones were randomly introduced on five percent of the trials. The results showed that performance on the probe trials often did not rise above chance, suggesting that the subjects did not become attentive until near the end of the foreperiod on which they had been overtrained.

The foreperiod effects demonstrated in these experiments are discussed in terms of possible attentive strategies a subject might develop when exposed to the various foreperiod sequences. Such strategies are assumed to be the result of a perceptual learning process involving the gradual acquisition of attentional responses to the warning interval; the strategies appear to differ in terms of the point in the foreperiod at which the subject's attention becomes optimal. For example, the data suggest that optimal attentiveness under the random foreperiod conditions occurs immediately after the warning signal, whereas under a fixed foreperiod condition it appears to occur at or immediately before the expected moment of stimulus presentation. This interpretation and its implications are discussed in detail in the final chapter.

Much of the rationale and many of the conceptions on which the procedural design and theoretical interpretation of these experiments are based, have come from the study of foreperiod effects in the areas of reaction time, tachistoscopic word recognition, and sensory threshold determination. In the Historical Review, reaction time studies are extensively discussed, primarily because reaction time has been the most frequently used task for the study of foreperiod effects, and so the questions raised by such studies are most relevant to this thesis.

Questions such as the length of the foreperiod required to produce optimal performance, the relations between absolute lengths of the foreperiod and performance, the relations between foreperiod variability and performance and, finally, sequential effects which might occur under conditions of foreperiod variability.

The effects of foreperiod length on sensory thresholds are also discussed, with special emphasis on the more recent studies concerned with tachistoscopic recognition thresholds, primarily in view of the theoretical interpretations put forward to account for such effects, as well as the similarity of these effects to those obtained on reaction time tasks. Of direct importance to this thesis is Newbigging's (1970) interpretation of random foreperiod effects on tachistoscopic recognition thresholds in terms of an "attention-distraction" hypothesis and Howarth and Treisman's (1958) "accuracy of time judgement" hypothesis used to account for fixed foreperiod effects on electric phosphene and auditory thresholds. The former hypothesis assumes that the warning signal acts as an instruction to the subject to attend to the place where the visual stimulus to be recognized will be displayed. This attentional response persists until the occurrence of a distracting stimulus or the stimulus to be recognized, whichever comes first. According to the latter hypothesis, the warning signal comes to act as a temporal reference point, allowing the subject to use his knowledge of the foreperiod length in order to anticipate the arrival of the critical stimulus, and to lower his threshold when he expects it. The accuracy with which the subject can anticipate the moment at which the stimulus will occur is assumed to be proportional to the length of the interval to be estimated.

CHAPTER TWO

HISTORICAL REVIEW

Wundt (1880) reported that "The perception of an impression is facilitated when the impression is preceded by a warning which announces beforehand that it is about to occur" (p. 226). Wundt made this statement after noting that the use of a preparatory signal yielded faster reaction times than the omission of such a signal. In fact, he observed that with a constant foreperiod and extensive practice it was possible, at times, to reduce reaction time to a "vanishing quantity"; that is, the reactive movement sometimes could be made to occur during or even before the reaction stimulus.

James (1890) when discussing Wundt's experiments concerning the effects of a warning signal on reaction time, claimed that the peculiar theoretic interest of these experiments was their demonstration of expectant attention. Apparently when the impression is fully anticipated, attention prepares the motor centres to react immediately. James goes on to postulate, "As concentrated attention accelerates perception, so, conversely, perception of a stimulus is retarded by anything which either baffles or distracts the attention with which we await it" (James, 1890, p. 429).

Thus, it was relatively early in the history of psychology that the theoretical importance of the use of a warning signal was established with the employment by James of the concept of attention to account for the observed effects. Even at this time, however, many psychologists, especially of the British empiricist school, failed to give any notice to the concept of attention mainly because it implied a degree of reactive spontaneity which would be difficult to reconcile with a philosophy that the higher faculties of the mind were pure products of "experience", and experience was supposed to be something simply "given". Although James drew his empirical evidence, in part, from the reaction time studies carried out by Wundt, it should be noted that the investigation of foreperiod effects on reaction time and their theoretical interpretation were in a sense a tangential area of psychology since the line of reaction time investigation most diligently followed was to ascertain the time occupied by nervous and mental events.

As far as the concept of attention is concerned its later rejection by the Behaviourists, as being too mentalistic for a science of behaviour, resulted in an exclusion which only in recent years has been rescinded. At the present time the concept of attention has been vested with explanatory properties with respect to many phenomena in both perception and learning. Thus, in spite of its long history in psychology, the attentional formulations basic to this thesis are relatively recent in conception having been derived primarily to account for foreperiod effects observed on tasks other than that of RT, for example, tasks involving sensory threshold determinations (i.e. Treisman, 1958) and tachistoscopic letter-sequence recognition (i.e. Lake and Newbigging, 1970).

Foreperiod Effects in Reaction Time

On the basis of historical precedence, any discussion concerning the effects observed when foreperiods are manipulated must of necessity include a review of reaction time studies since this task has been the one most frequently used to study such effects. Such studies have raised questions that are relevant to this thesis in that they are similar to those raised when foreperiod effects are investigated using other experimental tasks. Questions such as the length of the foreperiod required to produce optimal performance, the relationship between absolute length of the foreperiod and performance, the relationship between foreperiod variability and performance and, finally, sequential effects which might occur under conditions of foreperiod variability. In the next few pages, the general findings from the areas of reaction time research defined by such questions are briefly reviewed.

RT as a function of the absolute length of foreperiod.

The results of one of the earliest investigations in experimental psychology established that RT varied as a function of the absolute length of the foreperiod employed, very long intervals being unfavourable. As far back as Breitweiser (1911), the relations between foreperiod and RT were under analysis and for extended and more complex purposes, they continue to be under analysis during modern times (e.g. Klemmer, 1956; Karlin, 1959; Drazin, 1961; Botwinick and Brinley, 1962; Hermelin and Venables, 1964; Hohle, 1965). Of continuing interest is the question of the optimum interval to produce the quickest reaction (e.g. Woodrow, 1914, 1916; Freeman, 1937, 1938; Lansing, Schwartz and Lindsley, 1956). It is characteristic of the simple RT task that the subject knows in advance just what stimulus will be presented and just what response he is to make. Thus, it is almost a matter of course that the quickness of reaction will depend on the adequacy of the preparation. Early investigators such as Telford (1931), Breitweiser (1911) and Woodrow (1914) reasoned that the subject's readiness to respond in the reaction time situation might be controlled and varied, at least in part, by the duration of the foreperiod. If the foreperiod is too short, the subject may not have time to "set" himself - to prepare himself. If it is too long, his readiness, as the interval wears on, may fade away. Thus experimental investigations were carried out in an attempt to determine the duration of the foreperiod that would result in maximum readiness, as indicated by the fastest reaction times.

Breitweiser (1911) found definite individual differences in the length of the optimal foreperiod and reported a range of optima between 1.0 and 4.0 seconds. Woodrow (1914) using three subjects investigated fixed foreperiods of from 1.0 to 36.0 seconds and found that the 2.0 second foreperiod gave the shortest RT. On the basis of his experiments, he concluded that between 2.0 and 4.0 seconds was necessary to reach full "attention". In spite of the fact that this conclusion was based on data from only three subjects and that these data, as they were reported, do not allow for an estimate of the standard error of the means, the existence of an optimum foreperiod of about two seconds has been accepted by most subsequent reviewers (Woodworth and Scholsberg, 1954; Chocholle, 1963; Foley, 1959). Freeman and Kendall (1940) have estimated that if the standard error of the means of Woodrow's data were of the same order as those obtained in their study, there would be no significant difference between the 2.0 and 8.0 second foreperiods. In fact, Teichner (1954) has argued that Woodrow's obtained optimum actually may be best expressed as a range between 2.0 and 8.0 seconds.

The results of a number of more recent studies have provided a more direct contradiction of Woodrow's widely accepted conclusion. In the case of simple reactions both Davis (1940) and Klemmer (1956) have found that RT with a constant 1.0 second foreperiod is faster than with a constant 2.0 second foreperiod. Klemmer also considered the possibility that Woodrow's finding, that slightly longer reaction times occurred with a constant foreperiod of 1.0 second than with one of 2.0 seconds for each of his three subjects, might have resulted from the fact that the warning signal itself was, because of the procedure used, given at irregular intervals. However, an attempt to produce the effect experimentally failed. A fairly large number of investigators have even reported that reaction times obtained under a 0.5-second foreperiod condition are faster than those obtained under a 1.0 second condition (Karlin, 1959; Botwinick and Brinley, 1962; Sanders, 1965; Lansing, Schwartz and Lindsley, 1959; Nickerson, Collins, and Markowitz, 1969). In fact, for choice reaction, 0.5-second foreperiods have been found to be optimal in studies by Boons and Bertelson (1961) and Bertelson (1967).

Recent work thus shows that preparation can be built up much faster than Woodrow contended, but it has produced no comprehensive picture of the time course of the phenomenon, since there have been very few systematic studies of the effects of constant foreperiod lengths below 1.0 second. One reason for this is that most authors investigate simple reactions and in this type of situation, with short constant foreperiods, one is faced with the problem of preventing the subject from reacting to the warning signal. Shorter foreperiods have been utilized in experiments with variable foreperiods (e.g. Lansing, Schwartz, and Lindsley, 1959; Drazin, 1961). Lansing, Schwartz, and Lindsley (1959) measured simple RTs to flashes preceded at a variable interval in the range 50 to 1,000 milliseconds by another flash and found an optimum at about 350 milliseconds. In fact, however, it appears that to study the time course of preparation one must use constant foreperiods, since the use of variable foreperiods introduce range effects (Bertelson, 1965; Drazin, 1961). That is, the observed relationship between foreperiod length and RT appears to depend upon the range of the foreperiod lengths comprising a variable condition. Drazin (1961), for example, found that when the range of foreperiod lengths exceded 0.5 seconds, RT tended to decrease initially as a negatively accelerated function of the foreperiod. This relationship became more marked as the range increased.

Thus, at this point, one can conclude that as far as reaction time is concerned it is not obvious what foreperiod length will prove optimum. Teichner (1954) may well be correct when he states that the optimum foreperiod varies as a function of a number of variables including individual differences, intensity and duration of the stimulus, sensory modality, kind of instructions, and others. In fact, Teichner claims: "No single value seems acceptable as 'the optimum' since so many conditions are effective" (p. 138).

As stated above the investigators of simple reactions, especially with short foreperiods, have long been concerned with the problem of subjects "reacting" to the warning signal rather than to the reaction stimulus, such responses are seen as conveying no information about the reaction stimulus. The presence of these premature or false reactions also indicate that some of the shortest RTs are spurious, so that the subject's average RT is too small by an undefined amount. However, a number of procedures have been developed with the purpose of estimating the frequency of such errors and/or to reduce as much as possible their occurrence. One such procedure is to use "catch" trials on which the warning signal is presented but the reaction stimulus is omitted. Subjects are often practiced on a RT task, on which a certain proportion of the trials are catch trials (10 to 20%), until no responses are made on such catch trials. It is assumed that the subjects are then able to control their false reactions. They are then presented with the test conditions. Catch trials are also used to provide an estimate of the tendency to make premature responses in order to determine whether such errors are great enough to require correction or small enough to be ignored. Another procedure sometimes used is to omit from the calculations those trials on which very short RTs occur (i.e. RTs less than 100 milliseconds; Gibson, 1941) and/or have the subjects repeat such trials when they do occur (i.e. Klemmer, 1956, 1957; Karlin, 1959). The argument being that the increase in response speed is the result of reacting to the warning signal and thus disregarding the reaction stimulus. In addition to the above procedures most studies dealing with simple reaction time give the subjects specific instructions to respond only after the reaction stimulus is presented and not before. Most of the studies reported in this review of reaction time use at least one or more of the above approaches to account for errors. In recent years a number of mathematical models have been developed, primarily concerned with speed and accuracy trade-off in choice reaction time tasks, which have emphasized the necessity of a measure of error in order to determine whether the observed responses are controlled by the critical reaction stimulus and thereby reflecting the outcome of an underlying recognition process or whether the responses are merely "fast guesses" [i.e. the "fast guess" model by Ollman (1966) and Yellott (1967)]. According to the Ollman-Yellott model changes in reaction time latency as observed in simple reaction time tasks would be a function of changes in the number and/or the latency of guesses, as well as changes in the recognition process; however, without a measure of guessing one could not specify the proportion of the observed data representative of each. However, in light of the traditional procedures used to control the incidence of premature responses on simple reaction time tasks and of the robust effects to be reported, it would be surprising if the effects of the warning signal in simple reaction time could be "explained" solely in terms of random responding.

RT as a function of the variability of foreperiod.

From the time Wundt (1880) first reported that latency could be reduced by the use of a preceding warning signal, investigators have been interested in the comparative effects upon reaction time of foreperiods of both uniform and randomly varying lengths. Numerous studies have shown that reaction time is sensitive to both the duration and variability of the foreperiod (i.e. Mowrer, 1940; Huston, Shakow, and Riggs, 1935; Klemmer, 1956, 1957; Karlin, 1959; Botwinick, Brinley and Robbins, 1959; Zahn and Rosenthal, 1966; Bevan, Hardesty, and Avant, 1965; Bertelson and Renkin, 1966; Botwinick and Thompson, 1966; Botwinick and Brinley, 1962).

Two main results have been consistently demonstrated in these studies:- (1) Reaction time is a function of the absolute length of the foreperiod employed - the shorter the foreperiod length, the faster the reaction time, regardless of whether the foreperiods are fixed or vary randomly in length.[1] (2) A sequence of foreperiods of varying lengths is unfavourable to reaction time when compared with a sequence in which the foreperiod length is fixed; in fact, the greater the variability range, the longer the reaction time.

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1. This general conclusion may need qualification for foreperiod lengths shorter than 0.5 seconds, since at these lengths some investigators report an increase in reaction time, especially under random foreperiod conditions. However, down to approximately 0.5 second this relationship appears to be quite stable.

One possible explanation for the increase in RT, that is sometimes observed to occur at very short foreperiod lengths, might be found in the results of a number of experiments which suggest that events preceding the reaction-stimulus seem, under certain conditions, to restrict perception time; that is, the initiation of processes necessary for the perception of the reaction-stimulus appears to be delayed. For example, if two stimuli occur in close succession the perception of the second may be delayed until the first is perceived. Empirical evidence for such an interpretation has come from RT studies concerned with the "psychological refractory period" (e.g. Davis, 1957, 1959; Fraisse, 1957; and Bertelson, 1967). This is a descriptive term for the observation that when subjects are required to respond to two successive stimuli in close temporal proximity, the response to the second stimulus is found to be delayed. However, when this interstimulus interval is increased, the latency of the response to the second stimulus decreases. Davis (1959) reports the delay to be maximum when the successive stimuli are separated by 50 milliseconds, the shortest interval used in that experiment, and to be negligible when the interval exceeds 250 milliseconds.

Some explanations of this phenomenon are based on response mechanisms such as response interference. Other experimental results suggest, however, that the increased latency of response to the second stimulus may be due, as described above, to a delay in its perception. Davis (1959), for example, reported that even when no response to the first stimulus was required its mere presentation (and presumably its perception) was sufficient to delay the response to the second. He concluded on the basis of this and other experimental evidence that, "It is paying attention to a signal rather than performing any overt response to it which gives rise to delays in subsequent responses" (Davis, 1959; p. 211). The attended stimulus information apparently occupies a single-channel central processor and the reception of the additional information provided by the second stimulus is delayed until this processor is freed. A possible connection between the warning signal as used in the RT studies reviewed in this section, and the first reaction-stimulus in "psychological refractory period" experiments, is suggested in an unpublished experiment by Drazin (cited by Davis, 1959). It was noted in this experiment that the delays in RTs to a visual signal given shortly after a visual warning signal were nearly as large as would be expected if the subject had responded to the warning signal. Thus, it might well be, according to this interpretation that the time required to process the information provided by the warning signal prevents the perception of the reaction stimulus if the two stimulus events occur in close proximity.

These variations of reaction time in relation to foreperiods have generally been attributed to variations in states of expectancy or preparatory set (e.g. Mowrer, 1940; Woodrow, 1916; Gibson, 1941). It is generally assumed that the warning signal acts as a time cue to start some preparatory adjustment. However, whether such preparatory adjustment prompts the subject to be maximally "prepared to respond" to the reaction stimulus or whether it promotes a tendency for the subject to "anticipate the occurrence" of the signal is still very much a question for research. Earlier studies by Freeman (1937, 1938), Freeman and Kendall (1940) and by Davis (1940) suggested that preparatory sets were, in large part, muscular or motoric in nature as evidenced by the variation in degree of muscular tension occurring during the foreperiod. Mowrer and his colleagues (Mowrer, 1940; Mowrer, Rayman, and Bliss, 1940) and Weiss (1965) have argued for a central locus, that is "preparatory set" (expectancy, attention) that is mediated principally by neural rather than by neuromuscular mechanisms.

It is interesting to note that a number of the later investigators such as Weiss (1965) and Botwinick and Thompson (1966) have employed recordings of muscle action potentials (EMG) to argue for a central locus. Weiss fractionated total reaction time (RT) into two components. The time from stimulus onset to the appearance of the muscle action potential which he labeled premotor time (PMT). The duration from muscle firing to finger-lift response was considered the motor (MT) component. Thus, RT = PMT + MT. After investigating an irregular series of foreperiods in the range of 1.0, 2.0, 3.0, and 4.0 seconds, Weiss reported that MT was not a function of foreperiod but that PMT was. In fact, PMT was in the same functional relation to foreperiod as was RT. In this way the variation in set due to foreperiod.was seen to be a premotoric process.

Botwinick and Thompson (1966) extended Weiss' study by using a range of foreperiods from 0.5 to 15.0 seconds in both regular and irregular series. They also report that MT did not vary with foreperiod while RT did. They conclude, "RT set is a premotoric process, and probably a central one" (p. 14).

It should also be noted at this point that a number of more recent experiments have dealt with foreperiod effects on such "perceptual" tasks as sensory threshold determination (e.g. Howarth and Treisman, 1958; Treisman, 1964) and tachistoscopic recognition thresholds (e.g. Newbigging, 1970) which have yielded results highly similar to those found in RT. (These experiments and their results are reported in detail later in this review.) However, in view of the nature of the response required of the subjects in such tasks an interpretation of the foreperiod effects in terms of muscular or motoric preparation would not be reasonable, and indeed interpretations are generally in terms of expectancy and attention. That is, in such tasks where emphasis is not on speed of responding recognition and detection performance, for example, are, as in RT, best on the shorter foreperiods.

As far back as 1940, Mowrer published three hypothetical curves showing possible ways in which "readiness" might be assumed to develop during a 24.0 second foreperiod. According to these curves of the time course of preparation, "readiness" could either be pushed to the maximum immediately after the warning signal, thereupon to decline as the foreperiod length increased, or it could be pushed to the maximum at the expected moment of stimulus occurrence. Both would account for the observed relation between foreperiod length and RT latency since the latter assumed that the accuracy of stimulus expectation decreased as the length of foreperiod increased (Woodrow, 1930). These curves are remarkable in that current investigators of foreperiod effect upon RT as well as upon tachistoscopic detection and recognition thresholds are attempting to account for such effects in terms of hypotheses such as: "Fixed physiological arousal" hypothesis (Treisman, 1964), "attention-distraction" hypothesis (Newbigging, 1970), and "accuracy of time judgement" hypothesis (Treisman, 1964). Both the "fixed physiological arousal" hypothesis and the "attention-distraction" hypothesis predict maximum "readiness" immediately after the warning signal followed by a progressive decline. Alternatively, the "accuracy of time judgement" hypothesis would predict maximum readiness at the expected moment of stimulus presentation. (These hypotheses and their predictions will be discussed in detail in a later stage of this review.)

On the other hand, Klemmer (1956) has charged that all this discussion of the foreperiod effects in terms of readiness or set has led to a concentration upon the length of the foreperiod with little attention paid to foreperiod variability and to the most basic variable in RT, the degree of time uncertainty. By definition, the only uncertainty a subject has to face in simple reaction time is knowing when the stimulus will be presented. Thus, time uncertainty is seen by Klemmer to function both as a result of the subject's own imperfect time-keeping ability and the clock-time variability of the stimuli. The first factor varies with the length of a constant foreperiod and the second is defined by foreperiod variability. Klemmer carried out two experiments to adduce evidence that RT varies as a function of the subject's time uncertainty. In the first experiment, Klemmer investigated the effect upon RT of manipulating both the length of a constant foreperiod and the variability of a random foreperiod. The first manipulation was to provide evidence concerning the subject's own time-keeping ability, the second the subject's uncertainty as to the timing of the stimulus.

Using an auditory click as a warning signal and a 0.02 second light as a reaction stimulus, he found that for constant foreperiods of 8.25 sec., 4.25 sec., and 0.25 seconds, RT decreased regularly (269 millisec., 252 millisec., and 209 milliseconds). In the case of foreperiods having approximately the same mean duration (7.25 sec., 4.25 sec., and 1.25 sec.) but each made up of 11 intervals having a range of 2.0 seconds, the average RTs were slower (272 millisec., 259 millisec., and 259 milliseconds, respectively). A 4.25-second mean foreperiod having a range of 8.0 seconds yielded the slowest mean RT (281 milliseconds). Thus RT was found to increase as the foreperiod length and the range of foreperiods were separately increased.

Klemmer also looked at the pattern among foreperiods within each run in order to determine the effect upon RT. The longest reaction times were found when a short foreperiod was preceded by a long foreperiod (6 milliseconds average increase). However, when a long foreperiod was preceded by a short foreperiod, the shortest reaction times resulted (5 milliseconds average decrease). Two long foreperiods in a row or two short foreperiods in a row gave rise to reaction times equal to the mean reaction time in that series.[1] Woodrow (1914) had obtained results in

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1. Mowrer (1941) had previously demonstrated that the more irregular a given preparatory interval <u>in a series of reactions</u> (i.e. the greater its discrepancy from preceding regular intervals), the greater will be the lengthening of the reaction time. He interprets the effect of irregularity in terms of weakening the expectancy of a stimulus. Because of certain

the same direction, but of greater magnitude.

In his second experiment, Klemmer (1957) adduced further evidence in support of his hypothesis that the mean RT varies in direct proportion to the subject's uncertainty as to the timing of the stimulus. Here he attempted to estimate the variable error in the subject's time-keeping on the basis of "prediction" tests, in which the subject was required to reproduce intervals equal to the mean foreperiods of matched simple reaction tasks. Corresponding foreperiods and prediction variances were summed and a conversion made to information measures (bits) relative to the uncertainty of the individual subject's predictions of a 1.0 second interval. The relationship between RT and the time uncertainty of the stimulus plotted in terms of this informational measure was found to be approximately linear. The slope indicated that for every bit of stimulus uncertainty, RT increased an average of 18 milliseconds.

Karlin (1959) carried out an experiment in which he also investigated the effect of foreperiod duration and variability on reaction time. Eight subjects received an auditory warning signal separated from an auditory reaction stimulus by intervals of 0.5, 1.0, 2.0, and 3.5 seconds, which could be either constant or variable within a fifty minute session. In the constant condition (F) each of the four fixed foreperiods, during one session, was repeated in two blocks of 21 trials each, making up a total of 168 trials per session. In the variable condition (R) the 21 trials in each block were divided equally among three foreperiods, with

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1. (cont'd)
other aspects of this experiment which have a more direct bearing on this thesis, the author has elected to discuss this experiment in detail elsewhere in this review.

the median foreperiod of the three corresponding to one of the foreperiods of the constant condition, while the other two foreperiods were 20% above and 20% below this median, respectively. For example, the 1.0-second variable condition was composed of the following three foreperiods: 0.8 sec., 1.0 sec., and 1.2 second.

The results indicated that mean RT under both the constant and variable conditions became progressively slower as the foreperiod lengths increased from 0.5 to 3.5 seconds. Like Woodrow (1914), Mowrer (1941), and Klemmer (1956), Karlin also found that the reaction times obtained under the constant foreperiods were faster than the mean reaction times obtained under the corresponding variable foreperiods. Unlike the above investigators who found that as the range of foreperiod variability of a variable foreperiod increased progressively the mean reaction time increased progressively when compared to the reaction time observed under a corresponding constant foreperiod, Karlin found no such effect even though the range of foreperiod variability in his experiment increased progressively from 0.2 to 1.4 seconds under the variable condition. It should be noted these ranges were small when compared to the ranges investigated by Klemmer (1956) and Mowrer (1941).

Karlin also analyzed the RTs obtained on each of the three foreperiods making up a particular random foreperiod condition and found, in the case of the 1.0, 2.0, and 3.5-second variable foreperiods, that the shortest intervals yielded the slowest RTs; whereas the median and longest intervals yielded the fastest reactions. It is interesting to note that the RT levels obtained on these median intervals were very similar to the RT levels obtained on the corresponding constant foreperiods:- Median RTs of 256 millisec., 273 millisec., and 274 milliseconds, compared to the respective constant RTs of 256 millisec., 271 millisec., and 280 milliseconds.

Karlin rejected the idea that the resulting curves under the variable condition could be interpreted as empirical readiness curves (Woodworth, 1938). According to such an interpretation, the subjects in this experiment were least ready (longest RT) when the reaction stimulus occurred at the end of a short foreperiod, but increased their readiness with the additional time provided by the median foreperiod. Beyond the median foreperiod, readiness, if it did not actually increase, was at least maintained above that of the short foreperiod. This interpretation was rejected because the curves of the 0.5 second block demonstrated a reversal; it was the shortest intervals that yielded the fastest RTs.

Karlin, then, attempted to explain the resulting curves in terms of the effect upon RT of the length of the immediately preceding foreperiod. He postulated, as did Klemmer and Woodrow, that if a short foreperiod were preceded by a long one, the subject was likely to be caught "napping" and this would have an adverse effect upon RT. On the other hand, a long foreperiod preceded by a short one should yield faster RTs, since the subject, influenced by the short foreperiod, would get ready more quickly and stay ready longer. In this way, the consistently longer RTs obtained under the shortest foreperiods on the 1.0, 2.0, and 3.5-second blocks might be due to the fact that the shortest foreperiod was preceded more often by longer foreperiods. Karlin carried out a sequential analysis which suggested that this might be true for those particular foreperiod blocks. However, to account for the 0.5-second foreperiod data, he was forced to increase his number of postulates.

He claimed that in this case there was a tendency to get ready as fast as possible which was superimposed on specific tendencies resulting from the different preceding foreperiod lengths coupled with less ability to maintain a peak of readiness.

Karlin's experiment is outlined in some detail because a somewhat similar sequential analysis has been performed on the data of one of the experiments described later in this thesis. The results were such that the author was compelled to examine the method of investigation as well as the experimental design (within-subjects) as a possible explanation for such curves as those reported by Karlin.

In 1961, Drazin reported the results of an experiment in which the effects of foreperiod length and foreperiod variability on reaction time were investigated. Pronounced RT-foreperiod curves comparable to Karlin's were reported, although the foreperiod effect was distinctly greater when the preceding foreperiod was short. Karlin's data would suggest that the greatest effects occurred when preceding foreperiod was longer.

On the basis of earlier suggestions by Woodrow and Karlin that the RT-foreperiod relationship reflects progressive changes in the subject's state of readiness, Drazin formulated an "adaptation" hypothesis. According to this hypothesis, the effects of preceding foreperiods are attributable to an adaptation process: on the average, maximum readiness occurs at about the mean interval but this maximum tends to be reached earlier or later depending upon the length of the preceding foreperiod. In a later study, Zahn and Rosenthal (1966) suggested two mechanisms by which the point of maximum readiness might be influenced: by errors in time estimation and by the degree to which a particular foreperiod is "expected" (the relative frequency of a particular foreperiod length). In their view, a long preceding foreperiod leads to an overestimation of the duration of a shorter foreperiod, thus, resulting in longer RTs on such short foreperiods. The importance of such a "time estimation" mechanism will be seen when the hypotheses that have been developed to account for foreperiod effects on both tachistoscopic detection and tachistoscopic recognition thresholds are discussed in the following sections.

The Effect of Foreperiod Length on Sensory Thresholds

Although the effect of foreperiod length on reaction time has been extensively investigated, relatively little has been done concerning the investigation of such effects on other tasks. The reason for this, as stated earlier, is mainly one of historical precedence. One such task, however, on which the effect of foreperiod length has been investigated is that of sensory threshold determination. The importance of this small group of experiments to this review lies in the fact that the foreperiod effects observed have been somewhat similar to those obtained in RT studies. For example, as in RT, performance has been observed to vary as a function of foreperiod length; the shorter the foreperiod the better the performance as evidenced in this case by lower thresholds of detection (e.g. Newhall, 1923; Child and Wendt, 1938; Howarth and Treisman, 1958; Treisman and Howarth, 1959; Egan, Schulman, and Greenberg, 1961; Treisman, 1964; Watkins and Schjelderup, 1967).

We have seen that lengthening the interval between the warning signal and the reaction stimulus tends to increase reaction time (Woodrow, 1914). Newhall (1923, as cited by Howarth and Treisman, 1958), in an investigation of attention under two rather complex situations in which foreperiods of 0.0, 1.0, 4.0, 5.0, 10.0, and 17.0 seconds were utilized, obtained similar effects of foreperiod lengths on tactual and visual thresholds. He found that thresholds were lower under the shorter foreperiods.

Child and Wendt (1938) investigated the influence of a patch of light which could precede any one of five different intensities of a short duration tone by either 2.0 sec., 1.0 sec., 0.5 sec., 0.0 sec., or appear after this tone by 0.5 second. The tone intensities, separated by 2 db steps, were such that approximately half of them were below threshold. The level of tone intensity to be used was decided for each subject each day by a preliminary determination of the auditory threshold by the descending series of the method of limits, with the visual stimulation absent. A predetermined and counterbalanced random order of presentation of tone intensities and foreperiods was used for each of the eleven subjects involved in the experiment.

The results indicated that the frequency with which the subjects reported the tone increased as the foreperiod length decreased down to 0.5 seconds - the optimal time interval. When the light preceded the tone by one second or followed it by one half a second, small decreases in the number of tones detected occurred when compared to the 0.5 second optimum. Child concluded that this effect of the visual stimulus upon the auditory threshold "may be characterized as very small" (p. 116).

In a series of experiments carried out by Howarth and Treisman (1958, 1959) to investigate the effects of foreperiods on electric phosphene and auditory thresholds, it was found that thresholds as determined by the method of limits rose monotonically as the interval between the warning signal and threshold stimulus increased from 1.0 through 2.0, 3.0, 4.0, and 9.0 seconds. However, this rise was not found when randomly ordered foreperiods between 0.5 and 5.5 seconds were used. This particular result is contradictory to the one obtained by Child and Wendt above, as well as what is generally found when foreperiod length is randomly varied in RT studies (e.g. Telford, 1931; Botwinick, Brinley, and Robbins, 1959; Karlin, 1959, Thompson and Botwinick, 1966; Nickerson and Burnham, 1969) and in tachistoscopic recognition studies (e.g. Lake and Newbigging, 1970).

There are a number of features of the experimental procedure which may account for these unusual results obtained on the random foreperiod condition. In that particular experiment (Experiment V, Howarth and Treisman, 1958) five subjects were used which included the authors who had also served as subjects in a number of prior experiments using fixed foreperiods. In light of the results of one of the author's experiments to be reported, it may well be that performance under the random conditions was affected by so much prior practice under these various fixed conditions.

Egan, Schulman, and Greenberg (1961), in a "memory time" experiment, utilized a confidence-rating response type of tone detection task where a 1000-cps tone with a 0.25-second duration had 0.5 probability of occurrence on any trial. A 0.5-second light was used as the warning signal and could precede the tone by intervals of 0.25 sec., 0.5 sec., 1.0 sec., and 0 second. Eight subjects averaged highest detection scores with a foreperiod of 0.25 sec., while on the remaining conditions detection scores averaged progressively lower in the order 0.5 sec., 1.0 sec., and 0 seconds.

In 1964, Treisman reported an experiment dealing with effect of manipulating the duration of the (inter-stimulus) interval between an accessory stimulus and a "critical" stimulus to be detected. Part of this experiment seems pertinent to this review. In this experiment two neon-bulb light stimulus sources were employed; one served as a pre-warning and the other as the accessory stimulus. The accessory stimulus was followed after a period of time by the critical stimulus to be detected. Thus, each trial in the experiment began when the pre-warning light came on and was followed one second later by the accessory stimulus, both visual stimuli remained on until the subject had responded to the critical stimulus. The critical stimulus to be detected was a 50 milli-second intensification of a constant 500-cps tone. At the beginning of each session the subject's threshold was estimated by the method of limits, and two intensities of the critical stimulus, one "weak" and one "strong", 0.1 db apart, were chosen near the threshold. The interval between the accessory stimulus and the critical stimulus was defined as the inter-stimulus interval and the subject's task was to detect the critical stimuli under a number of different fixed inter-stimulus intervals: 0.25, 0.75, 1.25, 1.75, 2.25, and 2.75 seconds. During any one session equal numbers of strong and weak stimuli were randomly presented. In addition catch trials totaling 1/20 of all the actual signals were included. There were eight subjects involved in this experiment.

Treisman reported the mean percentages of positive response to both stimulus strengths. When the critical tones, both weak and strong, were preceded by the accessory light by an interval of 0.25 sec., the subjects obtained 62.5 percent correct detections, by 0.75 sec., 62.2 percent; by 1.25 sec., 51 percent; by 1.75 sec., 53.5 percent; by 2.25 sec., 49 percent; and by 2.75 sec., 44 percent.

These studies concerning the effect of foreperiod length on sensory detection thresholds are relevant to the current investigation for two reasons; First, they all demonstrate the effect of foreperiod lengths of short durations - that is, all have demonstrated that a monotonic relationship exists between the number of correct detections and foreperiod lengths, even for those intervals shorter than two seconds; from 0.25 sec., (Egan, Schulman, and Greenberg, 1961; Treisman, 1964) up to 9 seconds (Howarth and Treisman, 1958). Second, these studies, as the reader will see later, differ from the method of investigation used by the investigators of foreperiod effects on tachistoscopic recognition thresholds and are similar to the method employed in this current investigation in that all the subjects used were tested under each and every foreperiod condition. Thus, the method is characterized by relatively small numbers of subjects, but large numbers of trials per subject. Further, the task required of the subjects in these detection experiments involved a minimum memory component, that is, there was little or nothing that had to be retained from trial to trial in order to accomplish the detection of the critical stimulus.

<u>The Effect of Foreperiod Length on Tachistoscopic Recognition Thresholds.</u>

Verbal ready signals have long been used in tachistoscopic word recognition experiments to alert the subject to the impending presentation of the stimulus-word (Soloman and Postman, 1952; Postman, Bronson and Gropper, 1953; Newbigging and Hay, 1962). Although such a ready signal has been found to aid performance on such tasks, it has not been until very recently that the interval between a precise ready signal and the stimulus-word presentation has been experimentally manipulated in order to determine its effect on tachistoscopic recognition thresholds. In fact, the small amount of evidence that already exists has all been collected by Newbigging and his colleagues (Munoz and Newbigging, 1970; Lake and Newbigging, 1970; and Newbigging, 1970). It is from this set of experiments, however, that the original conceptions and rationale of this current investigation evolved, and thus, they require some discussion.

However, as important as the empirical evidence from these experiments is to this thesis, no less important is the theoretical framework used to account for this evidence. As stated earlier in this review the concept of attention until recent years has received but passing notice. In 1965, Newbigging put forward the suggestion that perceptual learning, as evidenced by the improvement of performance that occurs within a limited practice session on psychophysical judgements of all kinds, may well be mediated by the acquisition of attentional responses to cues relevant to the discrimination to be made. Within this framework foreperiod effects on tachistoscopic recognition thresholds are interpreted in terms of the warning signal or even the temporal interval itself coming to act as an instruction to the subject to attend to the place where the stimulus to be recognized will be displayed. Conversely, any extraneous stimulus of a distracting nature is seen to have an adverse effect on the effectiveness of this instruction. This theoretical framework will be discussed in detail later in this chapter, after the empirical evidence of these experiments is reviewed.

This group of experiments have all used the same basic procedures in order to investigate and analyze the effects of fixed and random foreperiods on tachistoscopic recognition thresholds. The investigators established recognition thresholds for each of a number of "complex" alphabetical sequences by means of the "ascending method of limits". Each subject involved in a particular experiment performed his task under one of several foreperiod conditions.

Munoz and Newbigging (1970) presented a sixty decibel, eight hundred and eighty cycle per second tone which terminated one, three, or seven seconds before the presentation of each of eighteen low frequency (1/3.6 million) nine-letter words. It was found that the recognition thresholds were a monotonically increasing function of the length of foreperiod.

Lake and Newbigging (1970) described the results of two experiments in which the effects of length and variability of foreperiod on tachistoscopic recognition were examined. The first experiment extended the above mentioned study (Munoz and Newbigging, 1970) by using twelve, seven-letter alphabetical sequences as the stimuli to be recognized and a much wider range of fixed foreperiods (0.5, 1.0, 1.5, 2.0, 4.0, 6.0, and 8.0 seconds). A random condition was also included in which the foreperiod had an average length of 4.75 seconds. For this condition, twenty intervals were used which ranged in length from 400 millisec. to 8,000 millisecs., the intervals differing by steps of 400 milliseconds. A tone of one second duration, 60 db intensity, and 880 cps served as the warning signal.

The results showed that the recognition thresholds increased monotonically as the fixed foreperiod lengths increased; that is, the shorter the fixed foreperiod, at least down to two seconds, the lower the tachistoscopic recognition threshold. Lake and Newbigging visually fitted a straight line to these data and put it forward as being suggestive of the form of the relation. For those fixed foreperiod lengths below two seconds, the recognition thresholds obtained were not significantly different from one another.

The results obtained under the 4.75-second random foreperiod are quite interesting. It was found that the mean threshold for the group under this particular condition was not significantly different from the mean threshold for the group under the 4.0-second fixed foreperiod condition. This result takes into account the performances on all the intervals making up the 4.75-second random foreperiod. If a comparison of the results of this experiment with the results for reaction time experiments is warranted, then one would expect that the performance under a randomly varying foreperiod would be inferior to the performance obtained under a corresponding fixed foreperiod because of the increase in time uncertainty induced by interval variability (e.g. Klemmer, 1956; Karlin, 1959; Botwinick, Brinley, and Robbin, 1959; Botwinick and Brinley, 1962; Botwinick and Thompson, 1966; Thompson and Botwinick, 1966). However, as stated above, it would seem that the unpredictable lengths comprising this foreperiod condition had no effect on tachistoscopic recognition performance. It should also be noted that information concerning the performances on the individual foreperiods comprising the 4.75-second random foreperiod of this experiment was not reported.

The second experiment described in the Lake and Newbigging study further extended the investigation of the effect of fixed and random foreperiods on tachistoscopic recognition thresholds. Using the same twelve, seven-letter alphabetical sequences as the stimuli to be recognized and the same one-second tone as the warning signal, fixed foreperiods of 2.0, 4.0, 6.0, and 8.0 seconds were investigated. In addition, four random foreperiods with means of 2.0, 4.0, 6.0 and 8.0 seconds were employed in order to further investigate the effects of foreperiod variability. Each of the four random foreperiod conditions was made up of seven intervals differing from one another by 0.5 seconds, having a range of variability of 3.0 seconds and a mean equal to 2.0, 4.0, 6.0, or 8.0 seconds. For example, the random 4.0-second foreperiod was made up of the following seven intervals:- 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, and 5.5 seconds.

The data of this experiment demonstrated that when the mean thresholds in milliseconds were plotted as a function of foreperiod length, the shorter the foreperiod the lower the recognition threshold. This relationship existed for both the fixed and random foreperiod conditions and, as in the previous experiment, could be adequately described by a visually fitted straight line. Again there would appear to be no effect of randomly varying the length of the foreperiods since performance on the four random foreperiods and on the corresponding four fixed foreperiods did not differ significantly.

As was noted earlier, this failure to demonstrate any effect due to foreperiod variability is somewhat surprising in view of what is known from reaction time studies. Lake and Newbigging attempted to a account for their results by citing Klemmer's study (1956) which showed that the effect of foreperiod variability is small even in RT, and that the degree of effect depended upon the range of variability. They state, "our failure to demonstrate any effect of foreperiod variability may be due to the small range of variability employed" (Lake and Newbigging, 1970, p.457). Later in this thesis the present author will also attempt his own hypothesis as to why no foreperiod variability effect was demonstrated in these two experiments.

In summary, this set of experiments provides evidence which would suggest that a monotonic relationship exists between foreperiod length and tachistoscopic recognition thresholds such that the shorter the foreperiod length (from 8.0 seconds down to 2.0 seconds) the lower the recognition thresholds. This relationship is found to exist regardless of whether the foreperiod lengths are fixed or variable from trial to trial. Furthermore, fixed foreperiod lengths 2.0 seconds and shorter (down to 0.5 second) not only yield the lowest thresholds but thresholds which do differ among themselves, thus demonstrating a range of optima from 0.5 second to 2.0 seconds. The finding of most interest was the failure to demonstrate any significant difference in performance between fixed foreperiods and random foreperiods having comparable mean values.

Theoretical Attempts to Account for Foreperiod Effects

This section outlines the various hypotheses that have been put forward by investigators to explain the relationship that seems to exist between foreperiod length and performance on both detection and recognition tasks. A perspective on the nature of this foreperiod phenomenon may best be had by an assessment of the conditions under which it is found to occur. That it is independent of the modality of the warning is suggested by the very similar curves following the use of lights (Howarth and Treisman, 1958; Child and Wendt, 1938; Egan, Schulman and Greenberg, 1961; Treisman, 1964) and bells (Howarth and Treisman, 1958) and tones as warning signals (Munoz and Newbigging, 1970; Lake and Newbigging, 1970; Newbigging, 1970).

That it is not modality specific has been demonstrated by the auditory threshold experiments of Child and Wendt (1938), Howarth and Treisman (1958, 1959) and Treisman (1964), by the visual threshold experiments of Newhall (1923), Howarth and Treisman (1958) and the Newbigging series (1970), and by the tactual threshold experiment by Newhall (1923). Furthermore, the phenomenon has been found to occur independent of the particular psychophysical method used; for example, Treisman and Howarth used both the "descending method of limits" and the "method of constant stimuli" (i.e. two near threshold strengths of a stimulus were alternated with "blanks" in a sequence determined from random number tables.), and Newbigging and his associates employed the "ascending method of limits". Finally, the phenomenon has been found to occur across experimental tasks; detection tasks using yes/no responses as well as confidence ratings, tachistoscopic recognition tasks using words and letter-sequences, and both simple and choice reaction time tasks. Thus, these studies taken together would suggest a central effect which might be thought of as a generalized readiness for a signal.

There have been at least three different hypotheses put forward to account for this generalized foreperiod phenomenon: A "fixed physiological arousal" hypothesis in which the relationship between foreperiod length and performance is thought to be merely a reflection of the time-course of the decay of the neuro-physiological processes underlying the arousal caused by the warning signal. An "attention-distraction" hypothesis and an "accuracy of time judgement" hypothesis; both of which attempt to interpret these performance curves in terms of a conception of attention that has been developed independent of neuro-physiological evidence. The "attention-distraction" hypothesis interprets the better performance obtained on the shorter intervals in terms of the subject's attentive behaviour being more effective at these foreperiod lengths, poorer performances on the longer foreperiods being due to the increased likelihood that the subject will have been distracted by an extraneous stimulus. The "accuracy of time judgement" hypothesis also claims that the subject is attentive with greatest effectiveness on the shorter foreperiods because such intervals are estimated with the greatest accuracy.

The author will, first, outline and attempt to evaluate the "arousal" hypothesis on the basis of existing neuro-physiological evidence; the remaining two hypotheses will be discussed within a perceptual learning framework. In order to provide an historical perspective a brief review of the literature in this particular area will follow with emphasis on the role of the foreperiod in perceptual learning.

Fixed Physiological Reaction: An "Arousal" Hypothesis.

In the last thirty years, work by physiological psychologists such as the studies by Lindsley (1951) and Moruzzi and Magoun (1949) have led to major changes in our ideas of nervous function. One such insight has come from the findings which would indicate that sensory input to the cortex can arrive there by two different systems: the classical projection system which appears to be the quick efficient route of information transmission and the diffuse projection system of the brain stem in which pathways are relatively slow and inefficient and which functions to arouse indiscriminately large areas of the cortex. On the basis of such evidence, Hebb (1949, 1955) has postulated that a stimulus may be considered as having both a cue and an arousal function; the arousal serving to tone up the cortex, thereby making it more receptive to incoming messages. Treisman (1964) put forward an arousal hypothesis as one possible explanation of the phenomenon associated with foreperiod effects on threshold levels. The warning signal, according to this hypothesis, caused an immediate arousal or alerting response, one effect of which was a rapid increase in sensitivity to incoming stimuli (i.e. detection or recognition stimuli). The threshold curves obtained were supposed to be a reflection of the time-course of the decay of the physiological change underlying this.

The postulates outlined in the above paragraph are strongly reminiscent of the old theory of the irradiation of cortical excitation. Hartmann (1934, p. 822), for example, suggests "that the neural activity originating in the occipital lobes spreads to other receptor areas of the cortex....and by subexciting those regions before or during specific stimulation increases the phenomenal intensity of the auditory experiences". Around this hypothesis grew a fairly large and confusing body of experiments dealing with the problem of sensory interaction. The bulk of these have been performed by Russian investigators and are summarized in a review by London (1954).

The evidence suggests that auditory-visual interactions do occur. Experiments by Kravkov (1936, 1937, cited by London, 1954), Hartmann (1933), Urbantschitsch (1888, cited by Gilbert, 1941) and Zietz (1931) all suggest that certain features of the visual process, such as acuity, brightness, and colour, can be influenced by auditory stimulation. Conversely, experiments by Urbantschitsch (1880), Hartmann (1934) , Thompson, Voss and Brogden (1958), Gulick and Smith (1959) have been cited as demonstrating the effect of visual stimulation on auditory sensitivity. It should be noted that an outstanding feature of the literature in this area is the lack of consistency in results which, according to Thompson, Voss, and Brogden (1958), is due to inadequate experimental design, poor experimental procedures and instructions, and improper statistical treatment.

In order to evaluate the relevance of the results of these experiments to the "fixed physiological reaction" hypothesis as proposed by Treisman, it is of crucial importance to ascertain the temporal relationships involved in concomitant stimulations. In spite of the contradictory nature of some of the results of studies investigating auditory-visual interaction, it would appear, as stated before, that auditory-visual interaction effects do occur. The crux of the matter is, however, that such sensory interactions are generally found to be maximum only when the accessory stimulus is employed simultaneously with the primary stimulus (Hartmann, 1933, 1934; Thompson, Voss and Brogden, 1958). As far as the all-important factor of extended temporal relationships are concerned, the Child and Wendt (1936) study is the one study most quoted as demonstrating the possible form of these relationships (Gilbert, 1941; Gulick and Smith, 1959). As was stated previously in this review (p. 22), this study dealt with the effect of randomly varying the interval (foreperiods 0, 0.5, 1.0, 2.0 seconds or - 0.5 seconds, negative precedence) between a visual stimulus (a patch of light) and an auditory detection stimulus (tone). However, in spite of being quoted by others, Child and Wendt, in light of their own results, were unable to decide whether the facilitation which occurred was interpretable "in terms of the summation of irradiated excitations in the central nervous system" or "to higher-order processes of judgement and attention" (Child and Wendt, 1938, p. 124). For one thing, although the 0.5-second foreperiod revealed the maximum facilitation (i.e. the largest number of tone detections) with simultaneous presentation of both the visual warning and auditory detection stimuli, facilitation was no greater than that which occurred on the one second foreperiod condition. This is not what one would expect in the light of other sensory interaction studies, where facilitation, if it occurred, did so with greatest effectiveness when both the accessory and primary stimuli were presented simultaneously.

Munoz and Newbigging (1970) addressed themselves to the problem of sensory interaction. In one experiment these investigators varied both the length of the fixed foreperiod and the intensity of the warning tone and noted the effect of these manipulations on word recognition thresholds. This experiment has been previously outlined, in part, on page 27 of this review. As noted before, when a 60 db tone was used as the warning signal, the usual relationship between foreperiod length and performance was observed. The lowest recognition thresholds occuring on the shortest of the fixed foreperiods, in this case the 1.0 second foreperiod. When the intensity of the warning tone was increased to 90 db, performance remained <u>identical</u> to that obtained when the 60 db tone was used, with one important exception. Performance under the 1.0 second foreperiod was now observed to be no better than that obtained under the longest foreperiod. That is, performance under the 1.0 second foreperiod on the 90 db condition was so obviously inferior to that obtained when the same foreperiod was used under the 60 db condition, that the investigators concluded that a warning tone of this intensity had a disruptive effect; but this effect, whatever its nature, was completely dissipated within three seconds since performance under foreperiod lengths at 3.0 seconds and longer was identical for both intensity conditions. It should be noted that Kravkov, in his experiments on facilitation and inhibition of visual acuity with white-on-black figures, found that "the effect of auxiliary stimulation lasted for four or five minutes" (Gilbert, 1941, p. 394).

In summary, these experiments indicate that if there is a facilitative (arousing or sensitizing) or an inhibiting (disruptive) process due to auditory/visual interaction, the temporal aspects of it appear quite short. This interactive process, when found, occurs maximally when the accessory (i.e. auditory warning signal) and primary (e.g. visual detection stimulus) stimuli are in close temporal proximity; in fact, when they occur simultaneously. Furthermore, the process appears to be effective only over a relatively short time span, probably not longer than four seconds. On the other hand, the monotonic relation found to exist between foreperiod and threshold level covers a much wider temporal range - up to fifteen seconds and beyond in some cases. Gulick and Smith (1959) may well be correct when they note "that shifts in thresholds due to sensory interaction are difficult to demonstrate" (p. 29).

Thus, it would appear that this one demonstrable "temporal" process, based on neuro-physiological concepts, is neither explicit enough, nor, from what is known, long enough in duration to be the basis of a fixed physiological hypothesis like the one proposed by Treisman.

In fact, as the Munoz and Newbigging experiment would indicate, once the interactive process has dissipated (within three seconds) the curve for the 90 db condition is identical with the curve for the 60 db condition, and this curve is of the same monotonic function that Treisman originally proposed his "arousal" hypothesis to explain. Both Treisman (1959) and Newbigging (1970) rejected the "arousal" hypothesis for the sake of other hypotheses.

Treisman rejected it because the particular monotonic relationship it predicted was not demonstrated under the random condition of his experiment (Note p. 23 of this review). He found no effect on threshold level when a random ordering of warning intervals between 0.5 and 5.5 seconds was investigated (Howarth and Treisman, 1958).

Newbigging rejected it because the results of the experiment described above as well as those of a number of other experiments which indicated that both the disruptive effect at the shortest foreperiod length (1.0 second) and the monotonic relation that still occurred on the two longer foreperiods could be more parsimoniously interpreted in terms of an hypothesis derived from attentional concepts - the "attention-distraction" hypothesis. Both the "attention-distraction" and "time-estimation" hypothesis have their roots in the general area of psychology designated by the term perceptual learning.

Perceptual Learning and the Role of the Foreperiod.

The term perceptual learning, for present purposes, refers to the improvement with practice of performance on a perceptual task. The perceptual tasks which are relevant are those which involve psychophysical judgement of all kinds: two-point cutaneous thresholds (Alluisi, Morgan and Hawkes, 1965), peripheral and foveal visual acuity (Bruce and Low, 1951), hue and pitch discrimination (Wyatt, 1945; Werner, 1940), pattern and word recognition from brief tachistoscopic displays (Hay, 1963; Newbigging and Hay, 1962; Newbigging, 1965), and repeated judgements of some stimulus dimension such as on the Muller-Lyer illusion (Parker and Newbigging, 1963; Newbigging, 1965). All these studies, regardless of the nature of the psychophysical task, demonstrate that the subject's performance improves as he continues to make repeated judgements within a limited practice session, the nature of this improvement being in the form of increased accuracy in judgement and discrimination. The amount of empirical data on improvement of this kind is extensive, and is readily available in review form (Gibson, E.J., 1953, 1963; Drever, 1960; Wohlwill, 1966).

There are two theoretical formulations specifically addressed to the problem of improved discrimination with practice, the stimulus specificity theory by the Gibsons (1955 a), and the association formulation of Postman (1955).

According to J.J. Gibson (1959), perceptual learning is the process of achieving and improving contact with the environment, of discovering new properties of the world by discriminating new variables in the stimulus flow. Thus, granting the assumption of a rich stimulus flux at the receptors, perceptual learning becomes a matter of differentiating the input (Gibson, 1955 a). According to this position, practice serves to reduce generalization among the stimuli, to increase precision of discrimination and to improve detection of relevant variables or distinctive features not previously noted. Thus, this information claims that the effective stimuli for perception are changed by learning such that the end result is an increased correspondence between response and stimulus properties. Perceptual learning, the Gibsons emphasize, is not a process of enriching the sensory core through the accretion of memories, images or elements of past experiences.

Postman (1955) argues that because stimulus response correlations change with practice, the Gibsons' theory assumes there must be changes in effective stimulus variables. In a very real sense, this theory is little more than a re-statement of the empirical facts, since it proposes no mechanism (s) by which stimulus specificity central to their theory comes about through practice. In another paper in the same year, the Gibsons (1955 b) reaffirm that they are indeed primarily concerned with the question of "what is learned in perceptual learning", deferring for the time being the mechanism (s) by which the learning comes about.

In opposition to the Gibsons, Postman (1955) formulates the problem of perceptual learning in traditional association terms. He points out that meaning often appears to involve enrichment and that the skilled performance involves a reduction of the need for sensory information even when it is available. As applied to the problem of present concern, the association formulation holds that "perceptual learning has taken place when the relative frequencies of responses undergo significant changes under controlled conditions of practice. Descriptively, perceptual learning is the attachment of new responses or a change in the frequency of responses to particular configurations or sequences of stimuli." (p. 440-441). For example, in the two-point cutaneous threshold experiments by Mukherjee (1933) and Alluisi et al, (1963), it is found that a certain degree of separation of the two points elicits the response "one" from the subject. However, with practice this same degree of separation comes now to elicit the response "two". It is such changes in S-R correlations that constitute the basic data from which perceptual learning is inferred.

These two theoretical formulations, however, both fail to give an adequate explanation of just how perceptual learning takes place. As was noted previously, the Gibsons' stimulus specificity theory does not propose any mechanism to account for how specificity comes about with practice, nor, as we shall see, how improved discrimination resulting from practice on one task may be positively transferred to a different task. It should be noted that James Gibson (1959, 1963) has tried to remedy this situation by referring to an amorphous conception of attention as the possible selector of stimulus properties to be responded to; he merely refers to, but does not elaborate on this. Association theory, using chaining devices and anticipatory responses, can discuss the perceptual learning effects but it too fails to specify a mechanism which mediates transfer.

Nevertheless, in the literature, a number of gross mechanisms have been mentioned. Wohlwill (1966) speaks of orienting reactions to a stimulus source, of scanning and focusing mechanisms, and of attentional constructs designed to handle changes in discrimination based on selection from a complex input. Pick (1964), for example, has found eye movements important for children, but Abelson (1963) found that they lose importance once the stimulus ceases to be unfamiliar.

As the basic mechanism of perceptual learning, however, Newbigging (1965) has made a strong case for learning attentional responses.

In attempting to account for the fact that with practice recognition thresholds for words decreased, Newbigging and Hay (1962) initially interpreted this practice decrement as resulting from a change in the response probability of the words in the frequency class being recognized. That is, for example, if the stimulus words in the recognition task were from the low frequency class, the subject, after recognizing several of the words as being of this class, would come to make his pre-recognition responses or guesses less frequently occurring words, thereby increasing the probability of being correct at progressively shorter durations over the list of stimulus words being presented. This hypothesis would also predict a relatively small practice effect for high frequency stimulus-words, as compared to that found for low frequency stimulus-words, since subjects were assumed more likely to give high frequency guess words as their initial responses.

Hay (1963) tested this hypothesis in an experiment where different groups of subjects were given practice on either a list of nine, seven-digit numbers; on nine, seven-letter low frequency words; on nine, seven letter high frequency words, or simply became adapted to the tachistoscopic situation. Following this practice all groups were transferred to the task of recognizing a common list of eighteen low frequency words.

Hay found high positive transfer from the high frequency word condition of the pretraining period to the low frequency word test condition; in fact, regardless of the type of pretraining received, there was no differential effect of it on the recognition thresholds of the low frequency test words. These results are quite inconsistent with a response probability theory. Hay, with the addition of more groups, varied the amount of pretraining on the high frequency words before shifting the subjects to the low frequency test list. This time, rather than increasing interference on the low frequency test (higher thresholds due to greater expectancy of high frequency words as a function of the amount of pretraining), the amount of transfer was a positive and direct function of the amount of pretraining.

When it was discovered that an apparatus-produced click occurred approximately two seconds prior to the presentation of the stimulus words in this experiment, Newbigging hypothesized that this click served as a precise auditory ready signal instructing the subject to attend to the place where the word to be recognized will be displayed. On the assumption that such an attentive response was gradually acquired during the course of the session, probably replacing other irrelevant attentive responses, the improved performance with practice might be accounted for.

Newbigging (1965) outlined and summarized his position and his proposal, that attentional responses might well be the mechanism which mediates the stimulus-response relations of perceptual learning, in the following manner:

> "Let me put the proposal in its simplest terms. Suppose we agree with the Gibsons that perceptual learning does consist of increased specificity of responses to stimuli. What is suggested is that this increased specificity is mediated by the acquisition of attentional responses to cues or stimulus dimensions relevant to the discrimination to be made. That is, as the Gibsons propose, perception is completely determined by the stimulus; but what constitutes the effective stimulus is what is attended to. The attentional response may be acquired to the stimuli which signal the presentation of the form, pattern, or word to be recognized in the case of brief tachistoscopic displays, or to the task-relevant dimensions of the stimulus pattern in cases where perceptual

> judgments about these dimensions are to be made. Judging the relative lengths of the horizontal lines in the Muller-Lyer illusion constitutes such a task. As a corollary of this increased attention to task-relevant cues or stimulus dimensions, we assume that the distracting effect of irrelevant cues or dimensions shows a corresponding decrease." (p. 312).

Most important is the fact that these attentive responses would be independent of the stimulus displayed and thus could mediate the positive transfer from one type of stimulus material to another. Thus, Hay's finding, that equal transfer occurred regardless of the type of pretraining given and that the degree of transfer was directly related to the amount of pretraining, is consistent with Newbigging's proposal.

It will be remembered that earlier in this review under the section entitled "The Effect of Foreperiod Length on Tachistoscopic Recognition Thresholds", (p. 25), a number of experiments carried out by Newbigging and his associates were outlined in which the effects of fixed and randomly varying foreperiod lengths on tachistoscopic word recognition thresholds were investigated. All these experiments demonstrated that, whether the foreperiod lengths were fixed or variable, the recognition thresholds were a monotonically increasing function of the foreperiod length (Munoz and Newbigging, 1970; Lake and Newbigging, 1970; and Newbigging, 1970). In fact, the results indicated that thresholds on corresponding fixed and random foreperiod lengths of 2.0, 4.0, 6.0, and 8.0 seconds were statistically equivalent; that is, randomly varying the foreperiod length had no significant effect (Lake and Newbigging, 1970). To account for these results, Newbigging formulated what is now called the "attention-distraction" hypothesis.

This hypothesis assumes that the warning signal (a tone, in the case of the experiments referred to above) acts as an instruction to the subject to attend to the place where the visual stimulus to be recognized will be displayed; this attentional response persists until the occurrence of a distracting stimulus, or the stimulus to be recognized, whichever comes first. The poorer performance (i.e. higher threshold levels) observed on the longer foreperiods are accounted for by the further assumption that as the foreperiod increases in length, the probability that a distraction will have occurred prior to the presentation of the stimulus to be recognized, also increases.

As an attempt to account for the somewhat surprising finding that performance on corresponding fixed and random foreperiod lengths were identical, this hypothesis appears to be most effective. According to the "attention-distraction" hypothesis, it is not whether a foreperiod length is predictable from one presentation to the next that is important, but rather the absolute <u>length</u> of the foreperiod on any given presentation. This hypothesis assumes the subject to be maximally attentive immediately after the warning signal, but as the interval between the warning signal and stimulus presentation increases the likelihood that the subject will have been distracted by an extraneous stimulus also increases; thus, performance level is determined by the foreperiod length regardless of whether a particular foreperiod is located within a fixed (predictable) condition or within a variable (unpredictable) condition.

As described earlier, Klemmer (1956), in a reaction time study, examined the patterning of the intervals making up a particular variable foreperiod condition and found that RTs were affected by the lengths of the preceding intervals. If a short interval was preceded by a long interval, the subject was thought to be caught "napping" and RT tended to be longer; while for the reverse condition, RT tended to be shorter. It might well be that something similar is operating under the random foreperiod conditions of Newbigging's experiments. The problem is, however, that the combined use of a between-subjects design and the ascending method of limits, in which recognition of the stimulus word is built up over a succession of presentations, does not allow for such a fine grained sequential analysis nor is the data refined enough to determine the effectiveness of each of the intervals making up a particular random foreperiod condition. One of the problems tackled in this present study was to develop a more sensitive procedure of investigation which would allow for such a fine grained sequential analysis of the resulting data.

Earlier in this review when discussing the possibility that sensory interactive processes might underlie the "fixed physiological-arousal" hypothesis as proposed by Treisman (1964), an experiment by Munoz and Newbigging (1970) was outlined in which the effects of 1.0, 3.0, and 7.0 second fixed foreperiods on tachistoscopic word recognition thresholds were investigated under two different intensity levels (60 and 90 db tones) of the warning signal. The results, it will be recalled, indicated that on the 1.0 second foreperiod there was a disruptive effect under the 90 db condition when compared to the performance (recognition thresholds) obtained under the 60 db condition. However, performance on the two longer foreperiods was identical under both intensity conditions with the shorter foreperiod of the two yielding the lower recognition thresholds.

Newbigging attempted to account for these results in terms of his "attention-distraction" hypothesis. He argues that because of the intense nature of the 90 db tone, it compels the attention of the subject, distracting him from the recognition task. Thus, when the visual display follows this tone after only a short interval the subject is unable to make the appropriate attentive readjustments for its perception. As the interval between the warning signal and visual display increases, however, time is available to make such attentive readjustments and the disruptive effects disappear.

While the "attention-distraction" hypothesis makes no formal statement about recovery from distraction, such a recovery is clearly indicated by the Munoz and Newbigging finding that the disruptive effect of the 90 db warning tone is no longer evident when the foreperiod is as long as 3.0 seconds. Under this foreperiod, the performances of the 60 and 90 db groups are indistinguishable. It must be assumed that distraction attributable to other stimuli also shows recovery. Not only does the above experiment demonstrate recovery from distraction, it also indicated that the effect of a distracting stimulus lasts for some time, at least up to one second following the presentation of the disruptive 90 db warning tone and possibly even longer. The problem is that at this stage in research, there is no specific empirical evidence as to the rate of recovery from distraction and its possible relationship to factors such as the physical characteristics of the distracting stimulus (i.e. intensity, duration), the modality concerned, and so on. However, the assumption is made in the "attention-distraction" hypothesis that as the foreperiod increases in length the probability that a distracting stimulus will have occurred also increases, thus predicting poorer performance on the longer foreperiod lengths.

In order to provide further support for this hypothesis, as opposed to an "arousal" hypothesis, Munoz and Newbigging (1970) studied the effects of 60 and 90 db warning tones in combination with the continuous presence or absence of a visual fixation point. Hay (1963) had previously established that substantial improvement in tachistoscopic word recognition performance could be obtained by use of a visual fixation point. Again the results indicated that poorer recognition performance occurred under the condition of the intense warning signal (90 db tone); on the other hand, with the addition of a fixation point, the effect of the intense tone was greatly attenuated. A logical assumption following from the "attention-distraction" hypothesis is that one way to maintain high performance is to reduce the probability of a distraction occurring. As stated before, it may well be that the intense tone had a distracting effect, but the addition of a fixation point enabled the subject to resist this distraction more effectively. The fixation point, like the 60 db tone, acted as an instruction to the subject to attend to the place where the visual display would occur.

The "accuracy of time judgement", the third hypothesis that has been formulated to account for foreperiod effects, is in one sense a special case in that it applies only to those tasks, be it one of reaction time or of tachistoscopic detection or recognition, in which the experimental events occur with regularity from trial to trial. That is, those tasks where the interval between the warning signal and stimulus presentation is constant or fixed from one presentation to the next.

Howarth and Treisman (1958) investigated the effect of fixed foreperiods on electric phosphene and auditory thresholds and found that these thresholds rose monotonically as the interval between the warning signal and threshold stimulus increased from 1.0 to 9.0 seconds. This increase was not found for the variable foreperiod condition. (Note p. 22 of this review for a more complete outline of this experiment.) Treisman (1964), in an attempt to interpret this result, formulated what he has called at times his "range of expectation" hypothesis and at other times his "accuracy of time judgement" hypothesis.

According to this hypothesis the warning signal comes to act as a temporal reference point, allowing the subject to use his knowledge of the foreperiod length in order to anticipate the arrival of the critical stimulus, and to lower his threshold when he expects it. Since he cannot determine the end of a time interval exactly, he will come to expect the stimulus over a range of time centred around the actual end of the interval. That is, the expected moment of occurrence of the stimulus will in fact be a range of times, the mean of which will be the actual foreperiod length. If, for example, the foreperiod is 3.0 seconds in length, the variability of the subject's estimation of this interval might result in his expecting the stimulus to occur say somewhere between 2.5 and 3.5 seconds after the warning signal, but not earlier or later than this period, and to lower his threshold only during this one second range. It is assumed that the threshold is lowered to an extent inversely related to the length of this range.

Central to this hypothesis is the assumption that the monotonic function generated by fixed foreperiod conditions is related to the accuracy of time judgement. Woodrow (1930) had eight subjects reproduce empty temporal intervals varying from 0.2 to 30.0 seconds. From the results he concluded that the error of time judgement is approximately proportional to the length of the time being judged. Thus, in terms of the "accuracy of time judgement" hypothesis, the accuracy with which the subject can anticipate the moment at which the stimulus will occur will be less for the longer foreperiods. "This decrease in accuracy might be expected to result in a decreased readiness for the stimulus and a consequent rise in the threshold." (Treisman, 1958, p. 138).

Woodrow (1914) attempted to explain his results with reaction times in terms of adaptation of attention. He claimed, on the basis of his results, that a subject could be maximally attentive for a finite period of time - up to two seconds, but at greater foreperiod lengths, since these longer intervals were estimated, the average level of attention would be less and thus the average reaction times would be longer.

Newbigging (1970) reports two experiments which demonstrate transfer effects on tachistoscopic recognition performance following different amounts of practice on various types of RT task (i.e. simple, discriminative and choice). The positive transfer observed is attributed to the learning of an attentional response to the foreperiod which was the same length for both the recognition and RT tasks. In the following paragraphs these experiments are outlined in greater detail.

In the first experiment simple, discriminative or choice reaction time tasks were combined factorially with foreperiods of 2.0, 4.0 or 8.0 seconds. Different groups of subjects were administered each of these conditions. Following reaction time practice, all subjects were shifted to a tachistoscopic recognition task in which they were required to recognize three alphabetical sequences of seven letters under the same foreperiod as they had had for the reaction time task. The data indicated that practice on the reaction time tasks results in positive transfer to the tachistoscopic recognition task where the foreperiod is of the same length for both. The data also indicated that the amount of transfer was dependent upon the type of reaction time training - choice resulted in the greatest transfer, followed by discriminative, and finally by simple.

The second experiment investigated the effect of the amount of reaction time practice on transfer to a tachistoscopic recognition task. The results of this experiment clearly established that practice on both simple and choice reaction time results in positive transfer to tachistoscopic recognition and that the amount of transfer depends on the amount of pretraining. It was also demonstrated that fewer choice than simple reaction trials are necessary to demonstrate transfer.

In both the tachistoscopic recognition task and the reaction time task the subject has the same requirement, to be attentive at the moment the stimulus is displayed. As previously stated when we outlined Newbigging's "attention-distraction" hypothesis, the warning signal acts as an instruction to the subject to attend to the place where the visual stimulus to be recognized (or reacted to) will be displayed. This attentional response, it was assumed, persists until either a distraction occurs or the visual display is presented. Now one way to reduce the probability of being distracted under a fixed foreperiod would be to make use of the regularity inherent in such a condition in order to anticipate the moment of occurrence of the critical stimulus.

Thus, the subject would be maximally attentive at the expected moment of stimulus presentation, and any distractions occurring up to this moment of stimulus presentation would be ignored.

The fact that the amount of practice on a particular reaction time task is a most important determinant of the degree of positive transfer that will be achieved, might well be due to the fact that the time adjustments necessary take time to be acquired; but when these time adjustments are acquired, they are independent of task specific variables. This might also account for some of the practice effect that occurs on both reaction time and tachistoscopic recognition tasks within a limited session.

Thus, the advocates of a "time judgement" hypothesis maintain that with practice on a fixed foreperiod a subject is able to more accurately judge the length of such a foreperiod and thus be better prepared for the stimulus presentation, be it in a reaction time task or a tachistoscopic detection or recognition task. There is some direct evidence that with practice, subjects come to improve the accuracy of their time judgements.

Woodrow (1930) had his subjects reproduce a one second stimulus-interval a total of 320 times and found the standard deviation in percentage to be 8.6. Hawickhorst (1934) with further training reduced this to 3.6%. Renshaw (1932) using five subjects for 159 days for a total of 19,080 trials reduced it further to 1.2%. The problem here is that we have no real knowledge of how long it takes a subject to reach a fair degree of accuracy, since Woodrow averaged his data in very large portions and in such a manner that practice effect within the session is lost.

At this point I would like to stress that both the "accuracy of time judgement" hypothesis and the "attention-distraction" hypothesis make the same over-all prediction concerning the effect of fixed foreperiods on performance, be it reaction time or tachistoscopic recognition thresholds. Both predict that the shorter the foreperiod length, the better the performance.

According to the "attention-distraction" hypothesis, the shorter the foreperiod the less likely it will be that a distracting stimulus will have occurred in such an interval. According to the "accuracy of time judgement" hypothesis, the shorter the foreperiod the more accurately the interval will be judged, thus, the greater the expectation precision as to when the stimulus presentation will be made. The latter hypothesis, however, is restricted in the sense that it can only be used to account for foreperiods which are of a constant duration and which are predictable from trial to trial. Also, since it provides a mechanism by which the subject can be maximally attentive at the expected moment of stimulus presentation, it would be reasonable to assume that any effects of an extraneous stimulus that might have occurred within the interval would thereby be reduced or eliminated. Thus, one would expect a higher performance level under a fixed foreperiod condition, if the time adjustments necessary have been acquired, as opposed to random foreperiod conditions where such adjustments are impossible and distractions are more likely to operate.

A somewhat similar position has been put forward by Gibson (1941), Woodrow, (1916), Mowrer (1940, 1941) and others to account for the well established fact in reaction time that an irregular sequence of preparatory intervals is unfavourable to reaction time as compared with a regular sequence (Note p. 11 of this review). Mowrer assumed that the irregularity affected reaction time by weakening the <u>expectancy</u> of a stimulus, and Gibson claimed that with practice, preparatory intervals of uniform length were favoured because the subject came to react to the time-interval itself.

As previously stated, the fact that Lake and Newbigging (1970) had failed to obtain any difference in performance when fixed and randomly varying foreperiods were compared on a tachistoscopic recognition task was somewhat surprising. It should be noted that both Munoz (1963) and Lake (1960) individually tried to account for the monotonic function observed under their fixed foreperiod conditions in terms of a "time estimation" hypothesis. Lake stated, "...learning is not as great in the case of long intervals as compared to short intervals because, since the long intervals are not as accurately estimated as the short intervals, attentional responses in the long interval situation do not receive the same level of reinforcement as responses in the short interval situation." (p. 59). The problem here was to show how an estimation hypothesis could account for the fact that his 4.75 second random and his 4.0 second fixed foreperiods yielded the same performance level - a fact reaffirmed when a later experiment found similar performance levels on fixed and random foreperiods of 2.0, 4.0, 6.0 and 8.0 seconds. Newbigging and Lake (1970), as we have seen, accounted for this fact by claiming it is not the predictability of the foreperiod length that is important, but the absolute length.[1]

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1. Although Newbigging has not, as yet, specified an estimation-type hypothesis, one can infer from his papers on transfer (Newbigging, 1970) that the basic mechanism for such a formulation exists in the form of a temporal conditioning of an attentional response. Thus, with practice "an attentional response to the temporal interval (foreperiod) is acquired" (p. 492).

The problem is, however, the subjects might well have made use of the regularity inherent in the fixed foreperiod conditions of these experiments in order to anticipate the occurrence of the critical stimulus, but the experimental procedure and the resulting data might not have been sensitive enough to demonstrate this attentive behaviour. In other words, there would be no way of knowing for sure whether the subjects under the fixed foreperiod conditions had utilized an attentive strategy as described by the "attention-distraction" hypothesis or a strategy like that described by the "accuracy of time judgement" hypothesis, since both hypotheses make the same prediction concerning overall performance on the various foreperiod lengths. Both predict that the shorter the foreperiod, the lower the recognition thresholds.

The Strength of "Expectancy"

In 1940, Mowrer reported an experiment on reaction time, the results of which are of most importance to this current study. One hundred subjects were first each given practice on twenty reaction tones at a constant inter-stimulus interval of 12.0 seconds. Following these twenty preliminary practice trials, each subject received immediately 49 additional trials (making 69 in all), which also came at 12.0 second intervals, except on the 21st, 27th, 35th, 41st, 48th, 55th, 61st and 68th trials. On these test trials, the tone occurred after intervals of 3.0, 6.0, 9.0, 12.0, 15.0, 18.0, 21.0 and 24.0 seconds, in a balanced random order. The average reaction times of all subjects on these eight test trials were calculated.

It was found on the 3.0 second interval that the reaction time was longest, as the test intervals approached the standard 12.0 second interval the reaction times became progressively shorter, until at the 12.0 second test interval the reaction time was not only fastest, but the same as that obtained on the 12.0 second interval when it was the standard. As the test intervals varied beyond 12.0 seconds, up to 24.0 seconds, the average reaction time again increased progressively.

These data were interpreted by Mowrer in terms of time judgement (expectancy). According to Mowrer, under the preliminary practice session, the subjects had come to anticipate the reaction stimulus to occur every 12.0 seconds, thus, they were maximally attentive at that time. When shifted to the test situation, rather than adopt a new strategy to suit the new random task, they still maintained their old expectation built up under the preliminary situation.

The importance of this experiment lies in that it suggests a possible way to determine the development and strength of a strategy built on accuracy of time estimation. It also provides evidence that when a subject is given both constant and variable foreperiods, as generally happens in a reaction time task, the order of presentation is important, for what is learned on one condition might very well affect the results obtained on the other.

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The experiments to be described in the following chapters of this thesis investigate the effects upon tachistoscopic recognition of a number of foreperiod variables such as length, variability and presentation order. These effects are discussed in terms of possible attentive strategies a subject might develop when exposed to the various foreperiod arrangements. An attempt is also made to obtain information concerning the subject's use of the regularity inherent in a fixed foreperiod condition, that is, to investigate in a more direct manner the development of a "time judgement" strategy.

CHAPTER THREE

EXPERIMENT I

Lake and Newbigging (1970) in a series of experiments, which were discussed in the previous chapter, investigated the effect of fixed and randomly varying foreperiods on tachistoscopic recognition thresholds of twelve seven-letter alphabetical sequences. They reported that regardless of whether the foreperiods were fixed or random the thresholds increased monotonically as the length of foreperiod increased. To account for this relationship the subjects were assumed to have developed an attentive strategy as described by Newbigging's "attention-distraction" hypothesis. According to this hypothesis, the warning signal comes to act as an instruction to the subject to attend to the place where the stimulus to be recognized will be displayed, and this attentional response persists until the occurrence of either a distraction stimulus or the stimulus to be recognized.

If such an attention strategy as that described by the "attention-distraction" hypothesis were adopted by these subjects, then additional empirical evidence for its existence should be obtained by analyzing the performance on each of the seven foreperiods comprising one of the random foreperiod sets. One would expect that the amount of information obtained towards the final recognition of the stimulus-word would also vary in relation to foreperiod length. The shorter the foreperiod within a random set, the greater should be its information contribution towards final recognition. These experiments all utilized the ascending method of limits in which recognition of the letter sequence is gradually built up over a series of successive presentations. Unfortunately, such a procedure does not allow for the recording of the data such that the contribution of individual foreperiods within a random set can be assessed. Thus, one of the purposes of the following experiment in its investigation of fixed and random foreperiod effects on tachistoscopic recognition was to utilize a procedure in which such information under the random foreperiod conditions could be obtained.

Lake and Newbigging (1970) also reported the finding that the performance under a given fixed foreperiod did not differ from the performance under a random foreperiod of the same mean length. This is a somewhat surprising finding, if a comparison of the results of this experiment with the results for reaction time experiments is warranted, because it suggests that performance under the fixed foreperiods as under the random foreperiods is determined solely by the absolute length of the foreperiod and that the predictability inherent in the fixed foreperiod condition is of no consequence. Reaction time under randomly varying foreperiods is generally found to be slower than that obtained under a corresponding fixed foreperiod, this inferiority being attributed to the increase in time uncertainty induced by interval variability. Thus, the primary purpose of the following experiment was to obtain additional information as to whether subjects, who have to perform a given tachistoscopic recognition task under various foreperiod arrangements, adapt their attentive behaviour in a manner appropriate to these foreperiod situations. Do subjects make use of the regularity inherent in a fixed foreperiod situation in order to be maximally attentive at the expected moment of stimulus presentation as described by Treisman's (1958) "accuracy of time judgement" hypothesis, which was discussed in the previous chapter, or do they attend from the occurrence of the warning signal until the stimulus to be recognized is presented as described by Newbigging's "attention-distraction" hypothesis? The following experiment was an attempt to find answers to such questions.

METHOD

The basic apparatus and procedures, which were common to both experiments, will be described in detail only for Experiment I. Differences in procedural detail of the second experiment will be described in its appropriate Method section.

Subjects

Eight students, four males and four females, ranging in age from 19 to 23 years and having good non-corrected vision served as subjects in this experiment.

Apparatus

Two test stimuli were presented for recognition, one per trial, in stimulus-field one of a standard three-field Scientific Prototype (Model GB) tachistoscope. The blank-field of the tachistoscope served as both the "pre-" and the "post-" exposure field.

A Spectra Brightness Spot Meter was used to monitor the brightness of the stimulus-fields. Stimulus-field one was maintained at twenty foot-lamberts and the blank-field at twenty-five.

A standard tone generator manufactured by Ashman Electronics provided a tone of one second duration, 880-cps, and 50-db, which was delivered binaurally via earphones to each subject and initiated every trial.

The apparatus was so set up that after once being initiated by the experimenter, the following recycling sequence was set in motion: a one second tone whose termination marked the beginning of the fore-period which could be either constant or variable from trial to trial depending on whether the foreperiod condition being investigated was fixed or random. This was then followed by a brief exposure of one of the two test stimuli and, finally, by an interval of three seconds duration in which the subject was to respond.

The duration of the tone, the various foreperiod lengths, and the response interval, were timed by means of a bank of nine Scientific Prototype Time Interval Generators.

On any one complete trial (from tone to tone), the particular test stimulus exposed and the foreperiod length presented were pre-programmed on paper tape and were thus fed, by means of a standard Tape Read-In, into their proper positions in the recycling sequence. The subject's responses were recorded both by hand and by means of a Gerbrand's Pen Recorder which was activated by the subject's pressing one of two response buttons corresponding to each of the two test stimuli.

Stimulus Material

The test stimuli to be recognized in this experiment appeared to the subjects as two circles, each one inch in diameter, inset with closely spaced fine black parallel lines on a white background (a photograph of Transograph shading film, pattern number L-22, manufactured by Chart-Pak, Inc., of Leeds, Massachusetts). In one circle these lines were sloped 36 degrees to the upper left (LEFT STIMULUS) and in the other circle, 36 degrees to the upper right (RIGHT STIMULUS).

In order to present these two stimuli, one on each trial and within the same stimulus-field, both were generated by changing the orientation of a single line pattern. The required change in line slope was accomplished by attaching this single stimulus pattern, which was circular in shape and one inch in diameter, to the flanged end of the shaft of a Sigma "Cyclonome" Stepping Motor mounted in stimulus-field one, such that the lines were straight up and down. This stimulus pattern was attached only after the shaft had passed through a hole, 1/4 inch in diameter, in the centre portion of a four by five inch index card mounted in a metal frame within the field; thus providing a stationary white background for the circular lined pattern. When properly pulsed by means of a read-in tape, the motor could be either stepped two 18-degree steps left or two 18-degree steps right, thus changing the orientation of the upright lines 36 degrees left or right. In an attempt to mask any noise the motor might make when activated, the stepping of the motor was synchronized such that it occurred only during the one-second tone. The motor was also enclosed in a sound-proof container.[1] Since stimulus-field one remained dark (during which time the blank-field was illuminated) until the moment of test stimulus presentation it was impossible for the subject to detect visually any change in line orientation while it was occurring.

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1. One reason for using this particular motor was that the only moving parts were its rotor, machined to a .0003 inch air gap tolerance, and its shaft supported by precision ball-bearings. Step braking was accomplished by the motors own permanent magnetic detent, that is, there was no mechanical braking system; thus, even without the above noise-control precautions the motor's activation could be described as exceptionally quiet.

Experimental Design

This experiment utilized a within-subjects design; that is, each subject received, in all possible combinations, each and every experimental variable. The subject's task was always to simply identify which one of the two test stimuli had been presented during a brief exposure and to register his choice by pressing the appropriate response button. This task was performed under various foreperiod conditions in which the foreperiod, over a given block of trials, could be either fixed or randomly varied in length.

The eight subjects were assigned to one of two groups such that each group consisted of two males and two females.

In Group I the four subjects G.S., W.S., B.S. and R.S. initially performed the recognition task under each of three random conditions in which the foreperiods varied randomly around a mean of 1.0, 2.0 or 4.0 seconds. Following this, these subjects repeated the same task, but this time the foreperiod lengths remained constant at either 0.5, 1.0, 2.0 or 4.0 seconds.

For Group II, the two types of foreperiod conditions were presented in reverse order. Here the recognition performances of the four subjects A.B., S.B., J.B. and A.A. were first investigated using fixed foreperiods of 2.0, 4.0 and 8.0 seconds and later performed with randomly varying foreperiods having a mean of 2.0, 4.0 or 8.0 seconds.

Each of the random foreperiod conditions mentioned above consisted of seven foreperiods whose average length was either 1.0, 2.0, 4.0 or 8.0 seconds, with the exception of the 1.0 second random foreperiod condition, the seven foreperiods used differed from one another by 0.5 seconds and had a range of 3.0 seconds. One of the seven foreperiods comprising a particular random condition was equal to the mean, three were shorter and three were longer. For example, the random 4.0 second condition comprised foreperiods of 2.5, 3.0, 3.5, 4.0, 4.5, 5.0 and 5.5 seconds. In the case of the 1.0 second random condition, the range was reduced to 1.5 seconds since the seven foreperiods differed in only 0.25 second steps.

Procedure

Since each subject was to perform the experimental task under all the foreperiod conditions represented in his group, it was necessary to establish for each subject an exposure duration for the two recognition stimuli that would remain constant over all the foreperiod conditions. The duration of the stimulus exposure selected was such that it yielded a relatively stable performance level of between 65 to 75 percent correct identifications on the 2.0 second random foreperiod condition for each of the four subjects in Group I. For Group II subjects, who received the fixed foreperiods first, the exposure duration that resulted in the same performance range on the 4.0 second fixed foreperiod was selected. Such a performance level on these two foreperiod lengths was selected because it allowed room to move "percentage-wise" when the other shorter and longer foreperiods were investigated.

The appropriate exposure duration for each subject was determined in the following manner. First the recognition thresholds for both test stimuli were estimated using the ascending method of limits. Each subject was instructed to put on the earphones through which a tone would occur, followed by an interval of two seconds which would terminate in the presentation of either of the two test stimuli. It was explained that, at first, the exposure of either test stimuli would be subliminal, but that the exposure duration would be increased until he could make three consecutive correct identifications of the particular test stimulus used. Blanks were used to assure that the subject was actually recognizing the stimulus presented. There were ten threshold determinations, five for each of the test stimuli in random order. The average of these ten thresholds was used as the exposure duration to start the subject under the experimental procedures central to this study. With continued practice and manipulation of the exposure duration under actual test conditions to be described below, the following stable durations of exposure were found for each subject: Group I; G.S. 14 millisec., W.S. 10 millisec., R.S. 21 millisec., and B.S. 9 milliseconds. Group II; A.B. 10.5 millisec., S.B. 15 millisec., J.B. 13 millisec., and A.A. 12.5 milliseconds.

Under the actual test situation each subject was run individually and was read the following instructions:

> "The task that you are required to do is a very simple one. In the viewer in front of you will appear two different line patterns. Both patterns are circular in shape; but one has lines slanted to the upper left whereas the other has lines slanted to the upper right."

At this point, each subject was shown the two recognition stimuli, each was identified again and labeled as LEFT or RIGHT. The instructions then continued:

> "Only one of these two patterns will be presented to you on any one trial. Your task will be to identify which one of the two had been presented. Since they will be presented only briefly there may be times when you feel no positive identification can be made; in such a case I want you to guess as to the one it might have been. You will register the choice you

have made by pressing one of these buttons here. If the pattern presented has lines slanted to the upper left, press the left button, but if they are slanted to the upper right, press the right button. You will be wearing earphones through which you will hear a brief tone. This tone will be followed shortly by a presentation of one of the two patterns. You then register your choice by pressing the appropriate button and wait for the tone again. Remember, guess if you are not sure. The purpose of this experiment will be explained to you after its completion. Do you have any questions?"

If there were questions, the relevant parts of the instructions were re-read.

Each subject was run individually for two sessions a day, each session lasting approximately one hour. No subject, however, had his sessions run consecutively.

Under the random foreperiod conditions the following occurred, regardless of whether these random conditions were investigated before or after the fixed foreperiods. Each subject was given 112 trials per session on each of the three random foreperiod conditions represented in his group. The first 14 trials served merely as practice and were later discarded. The remaining 98 trial-block provided data concerning the number of correct responses on that particular foreperiod condition. Within the 98 trial-block each of the seven foreperiods comprising a random condition was represented fourteen times, seven of these fourteen occurrences were combined with the left oriented stimulus and seven with the right. All were randomized throughout the trial-block with the restriction that no more than four left or four right presentations could occur in a row. From session to session the three trial-blocks corresponding to the three random foreperiod conditions were presented in a different balanced order. Under the fixed foreperiods the situation was also the same for both groups. Each subject received 110 trials per session under each of fixed foreperiods represented in his group; the first 10 of which were discarded practice trials.[1] Randomized throughout the remaining 100 trial-block were fifty left and fifty right presentations of the test pattern with the same restriction that no more than four of a kind could occur in a row.

The subjects of both Groups I and II each received, under the random and fixed foreperiod conditions, a sufficient number of test stimulus presentations to determine whether or not a significant foreperiod effect existed. Each subject was run a total of 10 to 16 sessions on each of the two types of foreperiods investigated, such that he received approximately 1500 trials under each of the different foreperiod lengths making up the fixed and random conditions (The actual number of sessions a subject received depended upon the strength of the foreperiod effects, if foreperiod effects were strong fewer sessions were needed for significance).

The percentages of correct identifications were calculated for each of the fixed foreperiods, for each of the seven foreperiods making up a particular random condition, and the overall average for each random set. In addition, the random foreperiod data of two subjects from Group I and two subjects from Group II were sequentially analyzed by computer in order to determine whether the performance on a given foreperiod was effected in any way by the length of the foreperiod immediately preceding it.

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1. The difference in the number of practice trials under the random and the fixed foreperiod conditions was due to the fact that, while attempting to equate as closely as possible the number of practice trials on both types of foreperiod, the experimenter felt that ten trials of a constant foreperiod length for each fixed condition was sufficient practice; whereas, fourteen trials under a particular random condition allowed each of its seven foreperiods to be presented an equal number of times (twice) in random order.

RESULTS

Figure 1 presents graphically the overall percentages of correct identifications made under each of the four fixed foreperiods and under each of the three random foreperiod conditions by the four subjects of Group I. These subjects received the random conditions prior to receiving the fixed. It is apparent from Figure 1 that regardless of whether the foreperiods are fixed or random, the percent correct is a function of foreperiod length. The shorter the foreperiod, the larger the percent correct. This relationship between the absolute length of a foreperiod and performance is similar to that demonstrated in RT (i.e. Klemmer, 1956, 1957; Karlin, 1959) and in tachistoscopic word recognition (i.e. Lake and Newbigging, 1970); thus, it was also predicted in this experiment. Figure 2 demonstrates that the above relationship holds for individual subjects and thus, is not a consequence of the summary procedures used.

The results of the chi-square tests, shown in Table I, performed to determine if the differences in the frequencies of correct responses between the various foreperiod lengths made by the above subjects, both individually and combined, were statistically significant. In the combined situation, the comparisons between the fixed foreperiod conditions of 0.5 and 1.0 seconds, 1.0 and 2.0 seconds, and 2.0 and 4.0 seconds, as well as the comparisons between the random sets of 1.0 and 2.0 seconds and 2.0 and 4.0 seconds all yield frequencies of correct responding which differ significantly in the direction predicted. However, there are a small number of comparisons, such as that between the 0.5 and 1.0 second fixed foreperiods for W.S. and the 1.0 and 2.0 second fixed foreperiods for both W.S. and G.S., in which the differences in

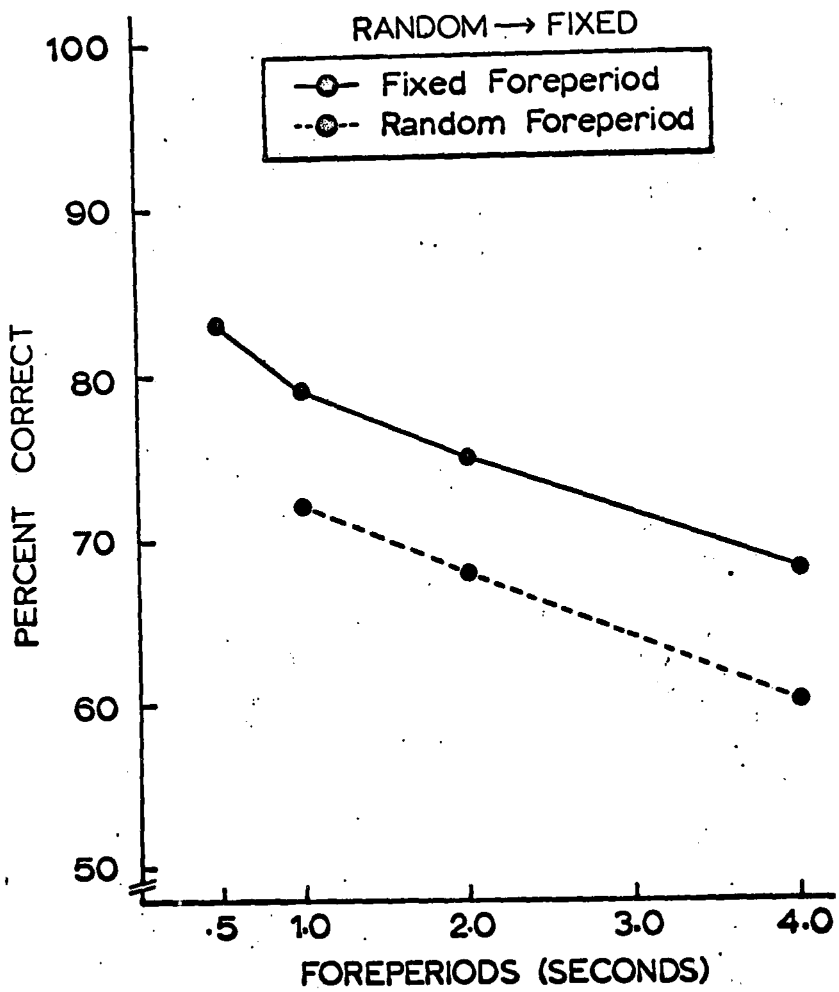

FIGURE 1. The percentage of the total number of correct identifications, made by the four Group I subjects W.S., G.S., B.S., and R.S. under each of the fixed and random foreperiods, as a function of foreperiod length (Experiment I).

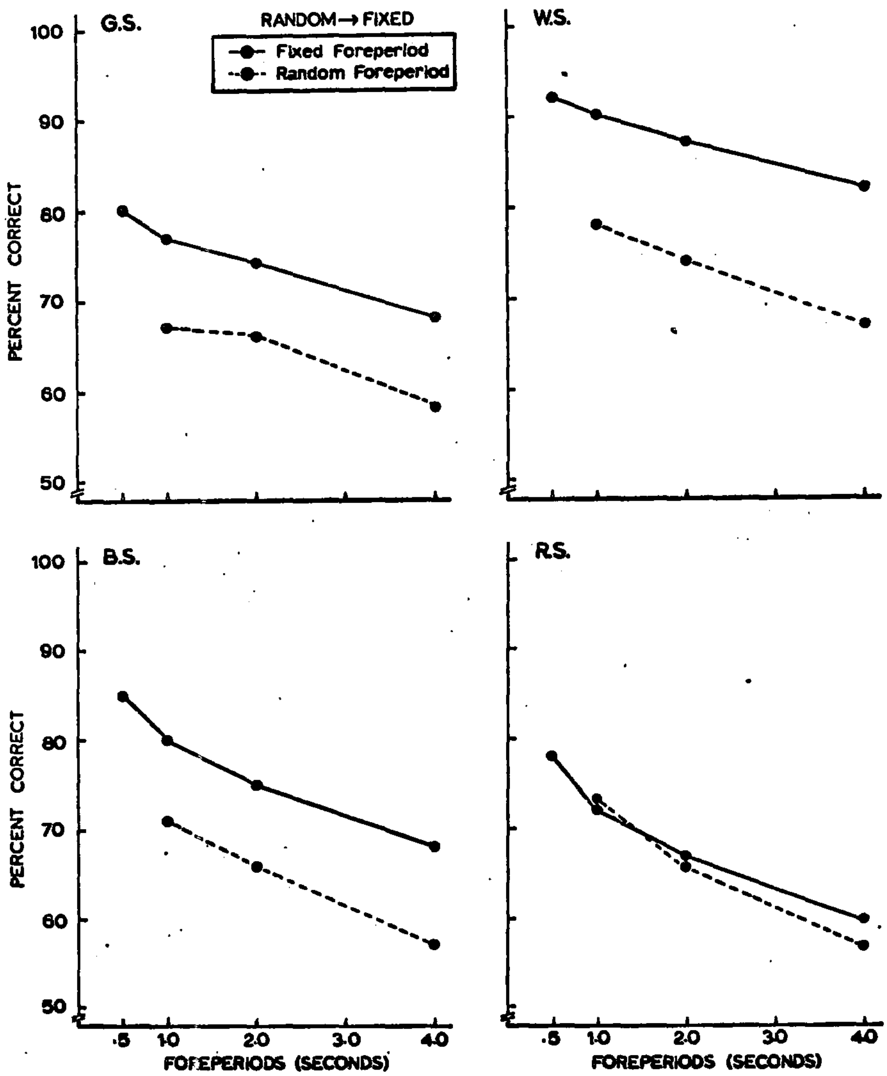

FIGURE 2. The percentage of correct identifications, made by the individual Group I subjects under each of the fixed and random foreperiods, as a function of foreperiod length in seconds (Experiment I).

TABLE I

Results of the Chi-Square Tests on Various Foreperiod Comparisons made under both Fixed and Random Conditions by Subjects of Group I and Group II.

Group I Subjects (Combined)

Comparisons Made	Fixed df	Fixed P	Random df	Random P
0.5 sec. - 1.0 sec.	1	.001		
1.0 sec. - 2.0 sec.	1	.001	1	.001
2.0 sec. - 4.0 sec.	1	.001	1	.001

Group II Subjects (Combined)

Comparisons Made	Fixed df	Fixed P	Random df	Random P
2.0 sec. - 4.0 sec.	1	.001	1	.001
4.0 sec. - 8.0 sec.	1	.001	1	.001

frequency were found not to be significant at the 0.5 level - although they were very close (.06). However, there were a number of features inherent in the data which a chi-square test did not take into account, but which when taken into account suggested that although the frequency differences on such comparisons were small; they were also significant. For example, of a total of ten sessions run by W.S. under the fixed conditions, nine of these sessions individually demonstrated the predicted relationship between foreperiod length and performance level. This is shown in Appendix A where the numbers of correct responses made under each of the foreperiod lengths per session are tabled for each subject. A rank order statistic, the Friedman Test, showed that the results for the subjects W.S. and G.S. were significant at the .01 level.

A similar relationship between performance and foreperiod length also exists under both the fixed and random foreperiod conditions for Group II subjects who received the fixed foreperiods first. Figures 3 and 4 illustrate respectively that this relationship holds for the group as a whole as well as for the individual subjects. The results of the chi-square tests confirm that the combined frequency of correct responding by all the subjects of this group under the various foreperiod lengths differed significantly. In fact, the comparisons between the 2.0 and 4.0 second and the 4.0 and 8.0 second foreperiods for both the fixed and the random conditions for the combined subjects were significant at the .001 level; with the shorter foreperiod length of the two compared yielding the greatest frequency of correct identifications.

From Figures 2 and 4, it can also be noted that for seven of the eight subjects used in this experiment, the fixed foreperiod conditions resulted in significantly higher percentages of correct responses than did the random foreperiods of the same mean length. This

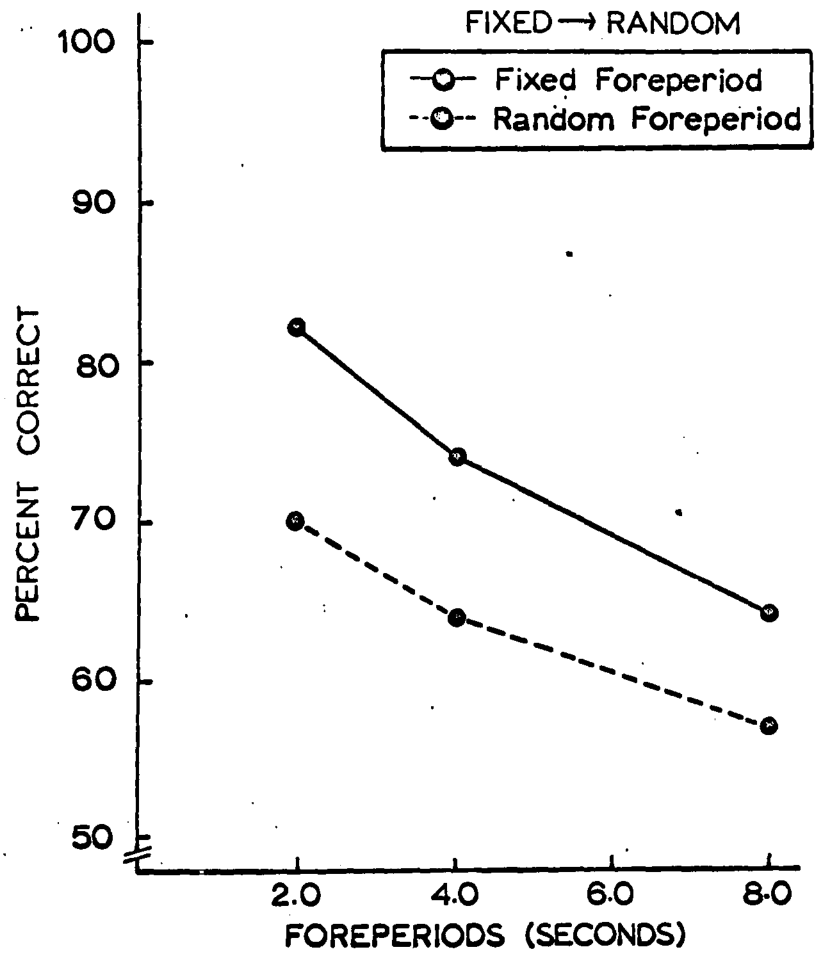

FIGURE 3. The percentage of the total numbers of correct identifications, made by the four Group II subjects A.A., A.B., S.B., and J.B. under each of the fixed and random foreperiods, as a function of foreperiod length in seconds (Experiment I).

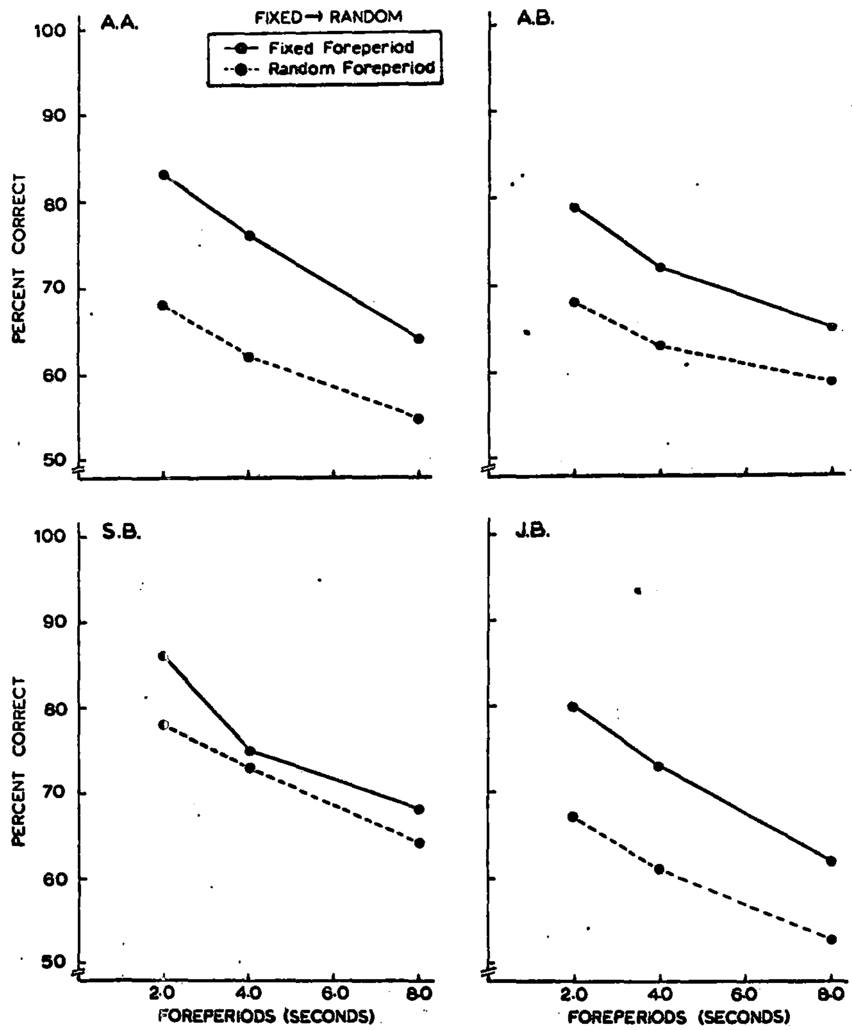

FIGURE 4. The percentage of correct identifications, made by the individual Group II subjects under each of the fixed and random foreperiods, as a function of foreperiod length in seconds (Experiment I).

finding differs from that reported by Lake and Newbigging (1970). In their study of foreperiod effects on tachistoscopic recognition, they found that randomly varying the foreperiod length had no significant effect on the recognition threshold.

Figure 5 summarizes graphically the percentages of correct responses made by the four subjects of Group I on each of the seven foreperiods comprising a random foreperiod condition. Each of the three performance curves represented in this Figure demonstrated quite clearly that for these subjects, who received the random conditions first, it is the shorter of the foreperiods which yield the highest percentages of correct identifications. Figure 6 shows that such performance curves are also generally characteristic at the level of individual subjects.[1] In Figure 7 the percentages for the combined number of correct identifications of these four subjects are re-plotted as a function of foreperiod length. However, this time the location of a given foreperiod with respect to its random condition is ignored. This Figure illustrates that the relationship between performance level and foreperiod length can be adequately described by a straight line with a slope of -4.44 and an intercept of 76.9. None of these points differ significantly from this line. This is an interesting finding because it suggests that performance is dependent primarily upon the absolute length of the foreperiod. That is, it would appear that it is of little consequence in which random condition a given foreperiod

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1. See Appendix A for a table which summarizes the actual numbers as well as the overall percentages of correct identifications made by the four subjects of Group I on each of the seven foreperiods comprising the three random foreperiods of 1.0, 2.0 and 4.0 seconds.

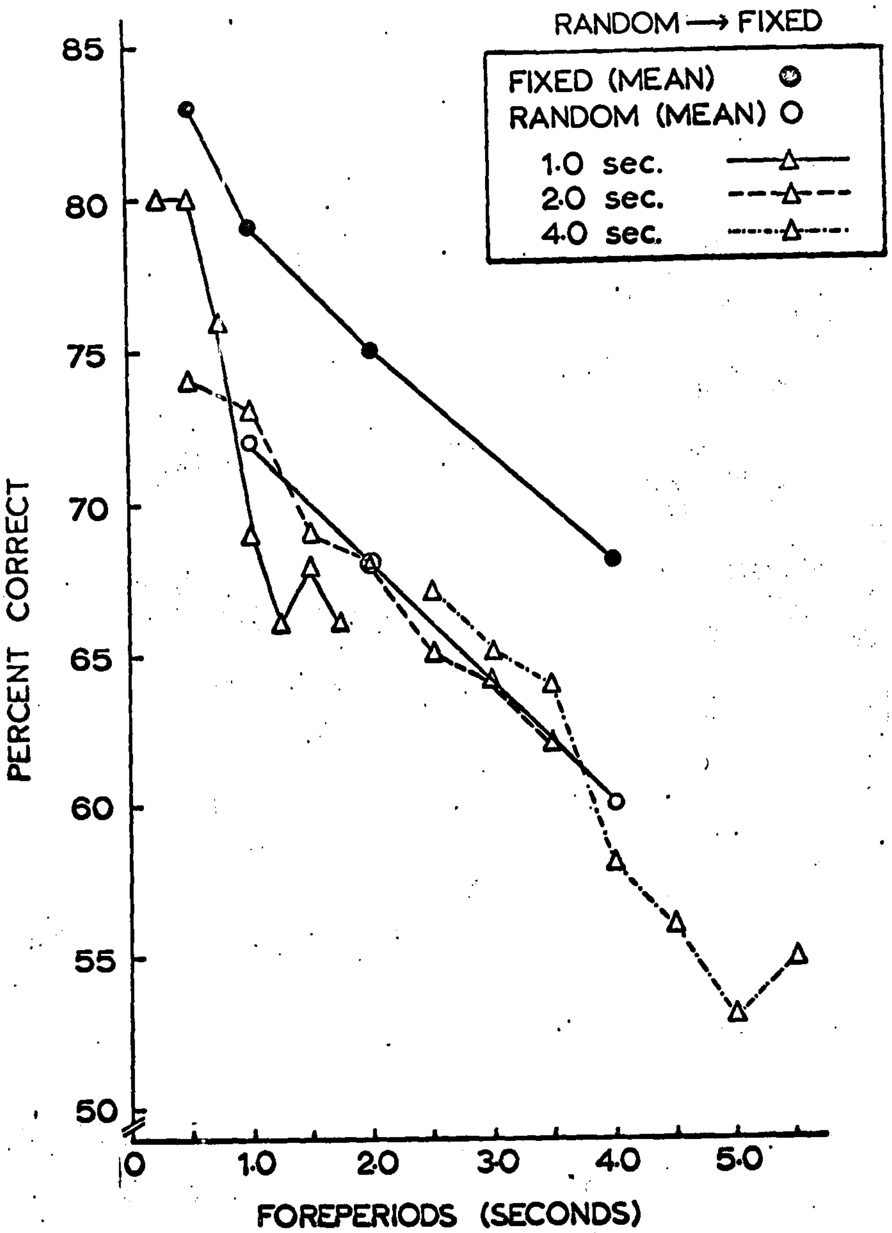

FIGURE 5. The relation between the percentage of correct identifications on each of the seven foreperiods to the overall percentage on each of the three corresponding random foreperiod sets, as well as the relation to the percentage obtained on each of the fixed foreperiods for Group I subjects (Experiment I).

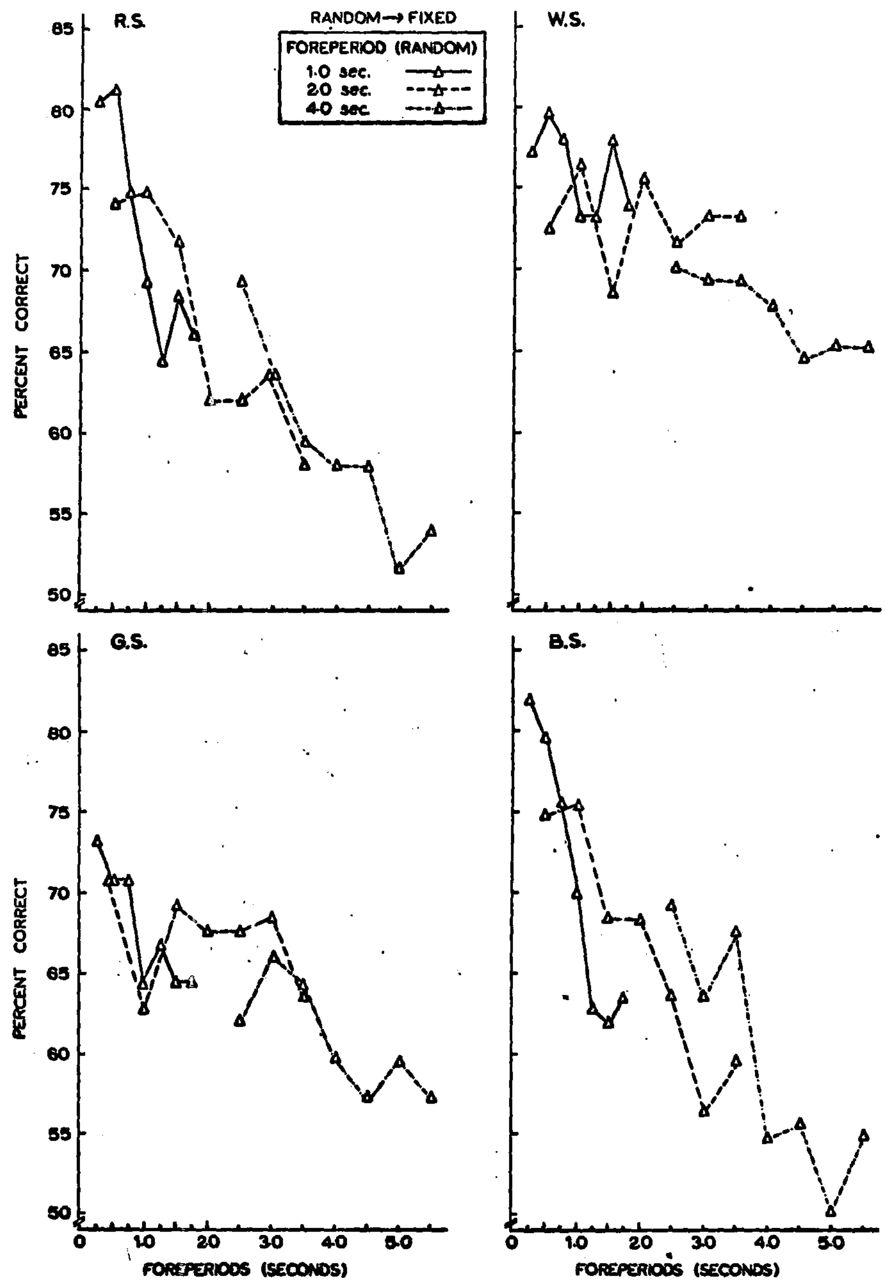

FIGURE 6. The percentage of correct identifications, made by the individual Group I subjects under each of the seven foreperiods comprising each of the three random foreperiod sets, as a function of foreperiod length in seconds (Experiment I).

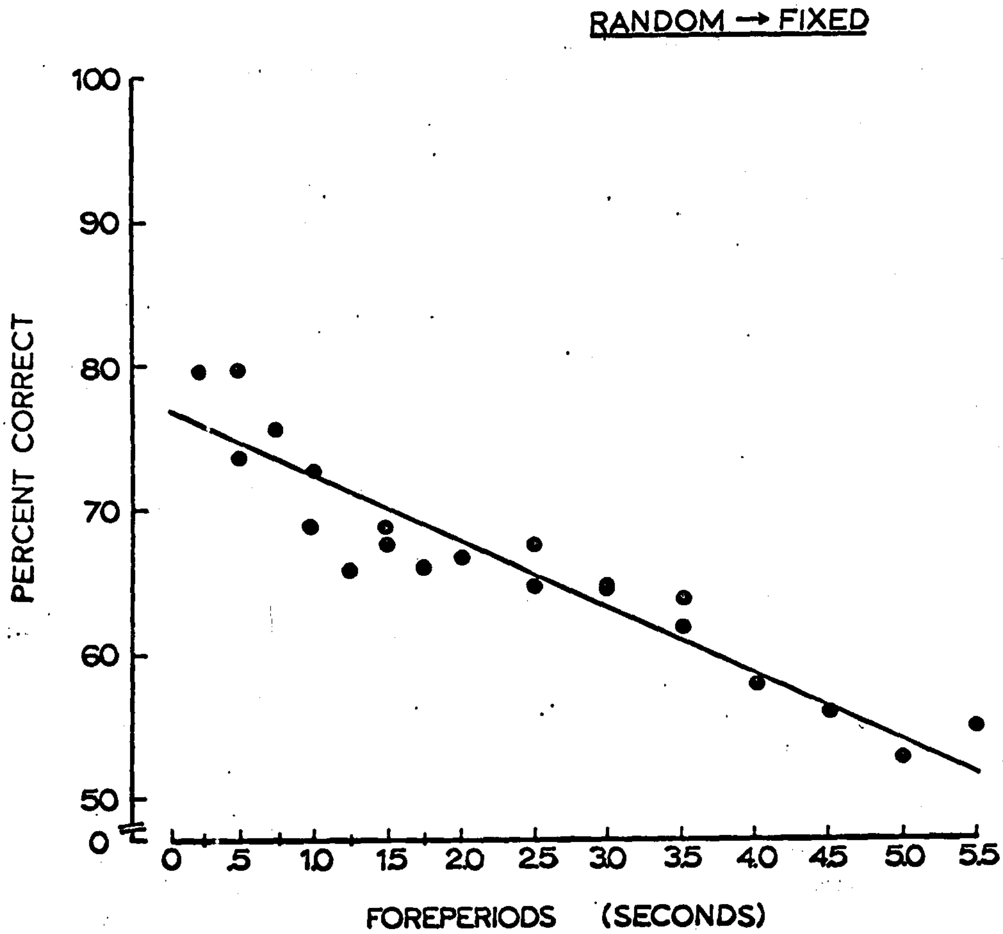

FIGURE 7. A straight line best fitted to describe the relationship between the percentages of correct identifications and the length of the foreperiods comprising the random foreperiod sets for those subjects of Group I who received the random conditions first followed by the fixed conditions (Experiment I).

length is located since the performance levels are the same; there would seem to be no context effect.

However, one can see from Figure 8 that in the case where the four subjects received the fixed foreperiods first, the shortest foreperiods comprising the three random conditions did not yield the highest percentages of correct identifications. In fact, under each of the three random foreperiod conditions, the foreperiod length resulting in the greatest number of correct identifications is the one immediately following the median foreperiod value: i.e. 2.5 seconds, 4.5 seconds and 8.5 seconds. It is also important to note from this figure that the median foreperiod lengths of 2.0, 4.0 and 8.0 seconds resulted in percentages very close to those obtained on the corresponding fixed foreperiods of 2.0, 4.0 and 8.0 seconds respectively. Figure 9 demonstrates that these curves are also generally characteristic of the individual's performance under the random conditions.[1]

Tables IIa and IIb summarize the results of a sequential analysis carried out on the random data of two subjects from each of the two groups in the experiment. The analysis involved looking at the performance levels under the shortest foreperiod length when it was preceded by each of the longer foreperiod lengths (Table IIa). The same was true for performance on the longest foreperiod when it was preceded

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1. See Appendix A for a table summarizing the actual number, as well as, the overall percentages of correct identifications made by these four subjects of Group II under each of the seven foreperiods comprising the three random foreperiods of 2.0, 4.0 and 8.0 seconds.

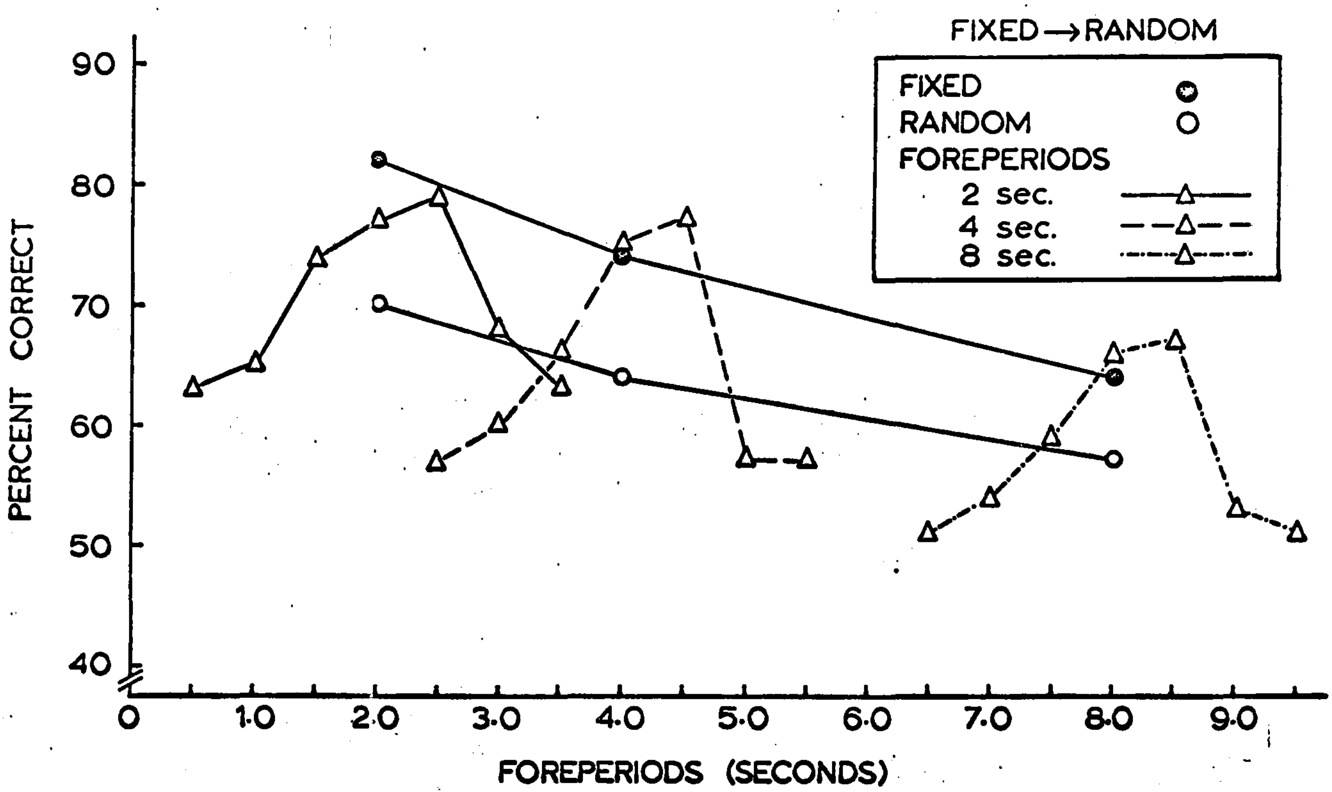

FIGURE 8. The relation between the percentage of correct identifications on each of the seven foreperiods to the overall percentage on each of the three corresponding random foreperiod sets, as well as the relation to the percentage obtained on each of the fixed foreperiods for Group II subjects (Experiment I).

TABLE II a

Summary of Sequential Analysis

Percentages of Correct Identifications made under the Shortest Foreperiod (1) of a Random Foreperiod Set when Preceded by each of the Longer Foreperiods.

Group I Subjects (W.S. & R.S.)

Random Foreperiod	Shorter ←		Foreperiod Length			→ Longer	
	1	2	3	4	5	6	7
1 sec.	89	76	81	77	86	85	80
2 sec.	66	85	75	76	67	73	80
4 sec.	63	77	72	67	79	66	65
TOTAL	72	79	76	73	78	75	75

Group II Subjects (J.B. & S.B.)

2 sec.	70	68	73	67	54	55	63
4 sec.	40	49	63	54	54	61	67
8 sec.	44	46	56	50	50	37	59
TOTAL	52	54	64	57	53	51	63

TABLE II b

Summary of Sequential Analysis

Percentages of Correct Identifications made under the longest Foreperiod (7) of a Random Foreperiod Set when Preceded by each of the Shorter Foreperiods.

Random Foreperiod	Shorter ←		Foreperiod Length →				Longer
	1	2	3	4	5	6	7
Group I Subjects (W.S. & R.S.)							
1 sec.	74	70	62	74	64	59	83
2 sec.	64	69	57	58	77	60	74
4 sec.	64	57	53	72	64	55	53
TOTAL	68	65	57	68	68	58	70
Group II Subjects (J.B. & S.B.)							
2 sec.	59	63	58	73	60	66	74
4 sec.	60	60	47	58	60	62	63
8 sec.	60	40	53	44	53	39	45
TOTAL	60	55	53	58	58	56	60

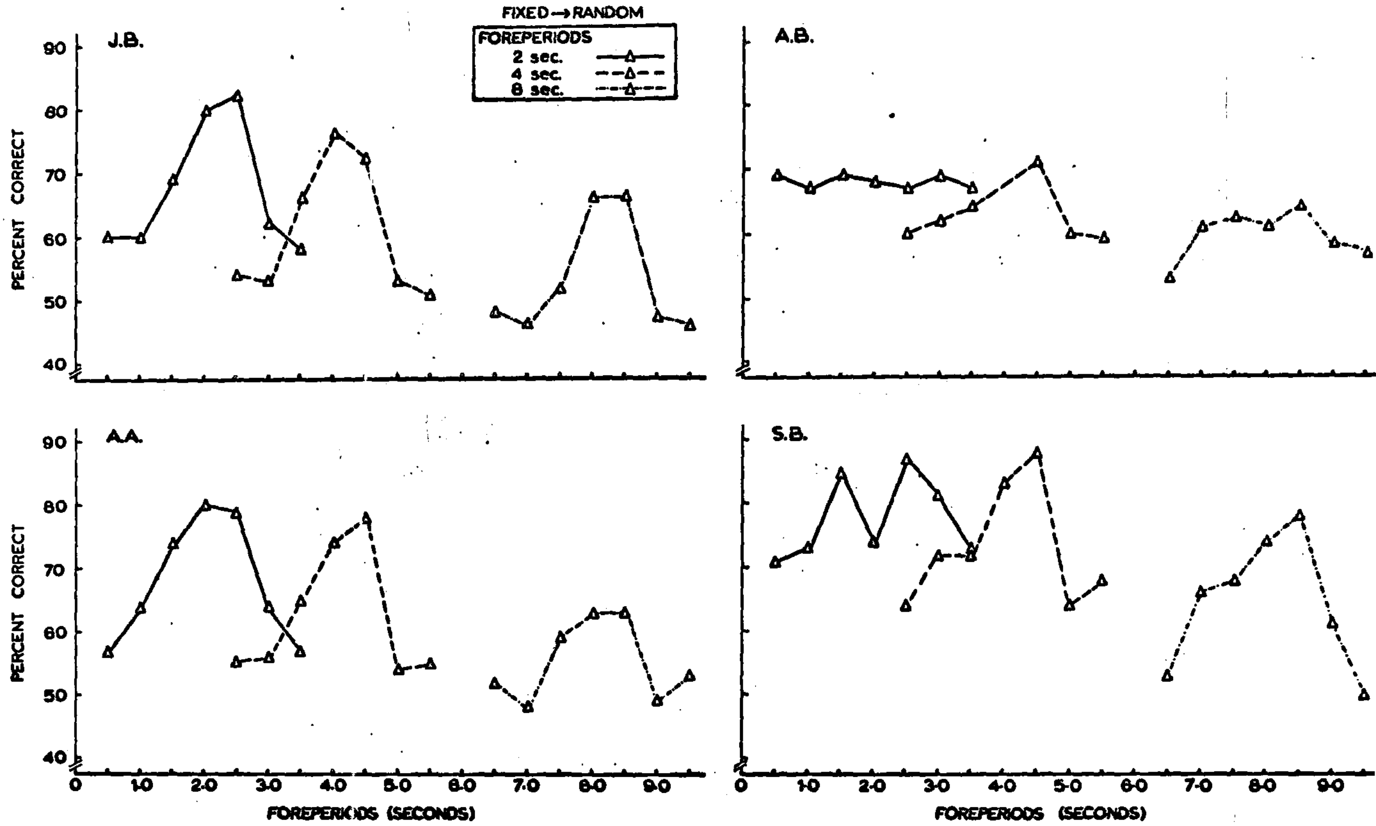

FIGURE 9. The percentage of correct identifications, made by the individual Group II subjects under each of the seven foreperiods comprising each of the three random foreperiod sets, as a function of foreperiod length in seconds (Experiment I).

by each of the shorter lengths (Table IIb). It is quite clear that the length of the preceding foreperiod had no systematic effect on performances under the shortest or longest foreperiod.

DISCUSSION

The results of this experiment indicate that the subjects may well be assumed to have adapted their attentive behaviour in a manner responsive to the experimental conditions under which they had to initially perform this recognition task. In addition performance under the different foreperiods comprising a random set depended upon whether the subjects had had prior practice on the fixed conditions. For those subjects who received the random conditions first, the finding that the percentages of correct identifications decreased as the foreperiod lengths increased, regardless of the random condition in which a given foreperiod might be contained, is consistent with the "attention-distraction" hypothesis.

However, there is nothing in the "attention-distraction" hypothesis which would predict that these subjects would perform consistently better when a given foreperiod is fixed than when it is a member of a random sequence. It would appear, on the basis of this and other empirical evidence to be presented, that under the fixed foreperiods Group I subjects may have made use of the regularity inherent in such a foreperiod condition. It may be, as Treisman's "accuracy of time judgement" hypothesis suggests, that subjects estimated the length of the foreperiods concerned and were maximally attentive at the expected moment of test stimulus presentation. Why this strategy should result in superior performance is at this stage highly speculative. One might postulate that with successive presentations of the test stimuli at a constant interval following the warning signal the attentional response becomes so strongly conditioned to this temporal interval that the subject becomes less likely to be distracted by an extraneous stimulus. This point will be discussed in greater detail in the final chapter. However, the fact that the percentage of correct identifications decreased as the fixed foreperiod length increased is accounted for in this hypothesis by its assumption that time estimates decrease in accuracy as the length of the interval to be estimated increases. Thus, a subject's expectancy concerning when a test stimulus will be presented is assumed to decrease in precision as the foreperiods lengthen. Group II subjects could also be assumed to have made use of the regularity inherent in the fixed foreperiod conditions they received, in order to anticipate the moment of stimulus presentation. However, the performance curves obtained under the random conditions, unlike those for Group I, demonstrated a well defined context effect with the median foreperiods of each of the random conditions yielding not only optimal performance, but performance very close to that obtained on identical foreperiod lengths under the fixed conditions. These results would indicate that when the Group II subjects were shifted to the random conditions they, instead of attending over the entire foreperiod, appear to have retained their previously learned strategy of estimating those median intervals upon which they had received so much prior practice under the fixed conditions.

The fact that what is learned under prior fixed foreperiod conditions might influence performance under the random conditions has been generally ignored by investigators of foreperiod effects. This has fostered attempts to explain the shape of the performance curves obtained under the random conditions in terms of the sequential effects of immediately preceding foreperiod lengths (Klemmer, 1956; Karlin, 1959). This will also be discussed in greater detail in the final chapter of this thesis.

In summary, the results of this experiment seem clearly to support the view that under the fixed foreperiod conditions the subjects developed an attentive strategy as described by the "accuracy of time judgement" hypothesis; whereas when the subject's first introduction to the recognition task involved the use of random foreperiods, an attentive strategy similar to that described by the "attention-distraction" hypothesis was adopted. However, when practice on the fixed foreperiod conditions preceded the presentation of the random foreperiod conditions, instead of adapting to these foreperiod conditions in the manner described by the "attention-distraction" hypothesis, the subjects, in this case, retained their old strategy of estimating those foreperiods of the random conditions on which they had received so much prior practice under the fixed foreperiod conditions.

The second experiment to be described in this thesis was carried out to investigate in a more direct manner the development of a time judgement strategy.

CHAPTER FOUR

EXPERIMENT II

This second experiment attempts to investigate more directly how attention develops within a foreperiod by utilizing a probe technique. Specifically in this experiment, subjects, after receiving practice under a fixed foreperiod, are presented a number of probe trials in which the stimuli to be recognized are presented prematurely. If the subjects should adopt an attentive strategy as described by the "attention-distraction" hypothesis, one would expect not only that performance on the probe trials would be better than that obtained on the longer regular practice foreperiod but that the shorter the interval between the warning signal and the probe, the better the performance. This, because the shorter the interval between the warning signal and stimulus presentation, the less likely it is that a distracting stimulus will have occurred. However, if the subjects should adopt an attentive strategy as described by the "accuracy of time judgement" hypothesis and thus estimate the length of the foreperiod used for practice, one would expect that performance would be superior on that foreperiod compared to performance on the probe trials. In fact, it would be predicted that the closer the probe was to the expected moment of presentation, the better the performance.

In view of this difference in the points of time where the subjects are assumed maximally attentive a probe technique should provide further information on the use of such strategies under fixed foreperiod conditions.

METHOD

Subjects

The subjects in this experiment were two experimentally naive undergraduate students; one male (J.P.) the other female (L.P.), both were 19 years of age and had good, uncorrected vision.

Apparatus and Stimulus Material

The stimuli to be recognized, as well as the apparatus used to present them to the subjects, were identical to that used in the previous experiment.

Experimental Design

As in Experiment I, a within-subjects design was employed. The subject's task was to simply identify which one of the two test stimuli had been presented during a brief exposure and to register his choice by pressing the appropriate response button. The subject received no feedback as to whether his choice was correct.

Each subject was first practiced under a four-second fixed foreperiod until an exposure duration for the two recognition stimuli was found which yielded a relatively stable performance level of between 75 to 80 percent correct recognitions. Test stimuli exposure durations of 8.5 and 9.5 milliseconds were found for L.P. and J.P. respectively. Following this, each additional 1000 trials of practice on this foreperiod length was separated by the investigation of a probe series of either 1.0, 2.0 or 3.0 seconds... A probe series was such that within a given block of trials, five percent had the recognition stimuli presented prematurely at either 1.0, 2.0 or 3.0 seconds after the warning signal; the remaining 95 percent were regular four second foreperiod trials.

One subject (J.P.) received the probe series in the order of 1.0, 2.0 and 3.0 seconds. The other subject (L.P.) received the probe series in the reverse order. For both subjects each of the three probe series was separated by approximately 1000 practice trials under the regular four second fixed condition.

Procedure

Both subjects were read the same instructions as were read to the subjects of Experiment I. Each subject was run two sessions a day, each session lasting approximately three-quarters of one hour.

Under the practice conditions each subject was given 200 trials per session until approximately 1000 trials under the four second fixed foreperiod were completed. Each 200 trial-block consisted of equal numbers of left and right stimuli presentations randomized throughout with the restriction that no more than four presentations of the same recognition stimulus could occur in a row. There were four different blocks of 200 trials used in this experiment, each having a different randomization of left/right presentations.

Under the probe series, ten of the 200 trials per session were premature presentations of the test stimuli at either 1.0, 2.0 or 3.0 seconds following the warning signal. Five of the ten were trials on which the left stimulus was presented and five were right stimulus presentations. The position of each of the ten probe trials within a given trial-block was determined by random selection. Once the positions were selected, however, they remained constant for the particular trial-block throughout the entire experiment. Both subjects received approximately 2000 trials on each of the three probe conditions of which 100 trials involved premature presentations.

The percentages of correct identifications made under the regular 4.0 second fixed foreperiod of both the three practice sessions and the three probe series (95%) were calculated and compared to the performance level obtained on each of the three types of probe trials (5%). Also calculated were the number of errors made on three trials preceding and following a probe trial.

RESULTS

Table III shows the percentages of correct identifications made under each of the three probe series by the two subjects in this experiment. It is quite clear for each probe series that the performances obtained under the probe trials are inferior to those obtained under the four-second foreperiod trials. In order to determine whether the poor performance under the probe trials might be due to the position of such trials among the four-second foreperiod trials of the probe series, the performance under the four-second fixed foreperiods of each practice session was parceled into two parts; the percentage of correct identifications when such a fixed foreperiod occupied a regular foreperiod position and when it would have occupied the position of a probe trial in a probe series. This was possible since, as described in the method section, the same recycling sequences of test stimuli presentation

TABLE III

The Actual Percentages of Correct Identifications made on the Four-Second Foreperiod Trials as well as on the Probe Trials of each of the Three Probe Series for each Subject.

Probe Series	Total Number Presentations (N)		Percent Correct	
	Four-Second Foreperiod	Probe Trials	Four-Second Foreperiod	Probe Trials
Subject J.P.				
1 sec.	2850	150	77	33
2 sec.	1425	75	81	52
3 sec.	1520	80	84	66
Subject L.P.				
1 sec.	2470	130	79	36
2 sec.	1900	100	86	48
3 sec.	1900	100	80	55

were used in both the practice and the probe series, what were probe trials in the latter case were regular four-second fixed foreperiod trials in the former case. Table IV indicates quite clearly that the performances obtained under the four-second fixed foreperiods in both positions (regular and probe) for each practice series are almost identical, thus indicating that the randomly selected probe positions were a representative sample of the whole.

It can also be noted from Table I that the performance levels obtained under the 1.0-second probe trials are below what one would expect by chance. Since there were but two possible stimuli to be recognized and only one could be presented on any one trial, one would expect by chance a fifty percent level of correct identifications. The fact is, however, that on a relatively large proportion of the probe trials the subjects missed the test-stimulus presentations completely and failed to make any responses. This occurred in spite of the fact that the subjects had been instructed to guess when they were not sure of the identity of the test stimulus presented on any particular trial. Table V presents for both subjects the numbers of errors made on the probe trials of each of the three probe series that were misses as opposed to incorrect identifications. It should be noted that the proportion of the errors that are misses decreases as the length of the foreperiod on a probe trial approaches that of the four-second foreperiod. Specifically, for the 1.0, 2.0 and 3.0 second probe series respectively the following percentages of the error that were misses were obtained for the subject J.P.: 40%, 39% and 30%, for the subject L.P.: 47%, 31% and 20%, and for both subjects combined: 43%, 34% and

TABLE IV

The Percentages of Correct Identifications made under the Four Second Fixed Foreperiod when it occupied a Regular Trial Position as well as when it occupied a "Probe Trial" Position on each of the Three Practice Sessions for each Subject.

Practice Session	Total Number Presentations (N)		Percent Correct Four-Second Foreperiod	
	Regular Position	Probe Position	Regular Position	Probe Position
Subject J.P.				
1	1045	55	68	67
2	950	50	79	78
3	1045	55	84	82
Subject L.P.				
1	760	40	72	73
2	950	50	83	84
3	950	50	81	80

24%. However, in the case of the four-second foreperiod trials of the three probe series combined, the total numbers of misses occurring on such trials were less than one half of one percent for either subject.

Table V also shows, for each of the three probe series, an adjusted percentage of correct identifications made on the probe trials for each of the two subjects in this experiment. This adjustment is based on the assumption that had the subjects responded on the missed trials one could expect that they would have correctly identified, on the basis of chance alone, the test-stimulus presented on half such trials. Thus, using the total number of probe trials presented on a given probe series, but adjusting the number of correct and incorrect responses by the addition of this assumed chance performance on the missed presentations, the adjusted percentages of correct identifications that are reported in this table were calculated. Even when the misses are accounted for in this manner the adjusted percentages of correct identifications made on the probe trials of a given series are still much lower than the percentages made on the four-second foreperiods trials of the same probe series (Note Table I). Statistical tests also indicate that when such an adjustment is made, the total numbers of correct identifications (actual numbers correct plus the numbers assumed correct if the subjects had respond to the misses) on the 2.0 and 3.0 second probe series for subject J.P. differed significantly (.05) from the fifty percent level of correct identifications expected to occur by chance, whereas none of the performance levels on the three probe series for subject L.P. differed significantly from chance.

In order to determine whether the presentation of a probe trial had any effect on the performances on the regular four-second foreperiod

TABLE V

The Number of Correct, Incorrect and Missed Identifications made under the Probe Trials on each of the Three Probe Series by both Subjects, as well as the Percentages of Correct Identifications Adjusted by Assuming that had the Subjects responded on these Missed Presentations they would have correctly Identified Half such Trials by Chance.

Probe Series	Total Number Probes	Number Correct	Number of Errors: Number Incorrect	Number of Errors: Number Missed	Adjusted Percent Correct
			Subject J.P.		
1 sec.	150	49	61	40	46
2 sec.	75	39	22	14	61
3 sec.	80	53	19	8	71
			Subject L.P.		
1 sec.	130	47	44	39	51
2 sec.	100	48	36	16	56
3 sec.	100	55	36	9	60
			Subjects J.P. and L.P.		
1 sec.	280	96	105	79	48
2 sec.	175	87	58	30	58
3 sec.	180	108	55	17	65

trials immediately following it, the number of errors made on the three four-second foreperiod trials immediately following a probe trial was compared to the number of errors to be made on the three regular trials immediately preceding it. Such a comparison was made since there was no reason to expect that a probe trial could influence the performances under the three trials preceding it, whereas this was not true for the three trials following it. One might expect, for example, that the probe presentation could "throw off" the subject's timing such that his anticipation of the regular presentations immediately following would suffer; on the other hand, it could conceivably sensitize the subject so as to make him more attentive on the trials immediately following, Table VI summarizes this analysis. It should be noted that not all the probe positions were included in this analysis, since there were a number of probe positions (15%) which due to random selection, were either not separated far enough in the recycling sequence or occurred at the beginning or end of the sequence such that there were less than the required three regular four-second foreperiod trials preceding or following the probe position. Only those probe positions separated by six or more regular trials were analyzed. It can be seen from Table IV that although in certain cases the first of the three trials following a probe yields the largest number of errors for that group, there are certain features of the data which when taken into account would indicate that the effect of a probe trial on the regular trials immediately following is negligible - if there is an effect at all. The numbers of errors made on the first trial of the three following trials on any given series are no greater, in most cases,

TABLE VI

The Number of Errors Made on each of Three Regular Four-Second Foreperiod Trials Preceding and Following a Probe Trial of a Particular Probe Series by Subjects J.P. and L.P.

Probe Series	Number of Errors: Three Trials Preceding 3rd	2nd	1st	(Pr.)	Three Trials Following 1st	2nd	3rd
Subject J.P.							
1 sec.	26	34	22		35	31	34
2 sec.	12	15	12		11	13	8
3 sec.	5	15	15		17	7	13
Total	43	64	49		63	51	55
		(156)				(169)	
Subject L.P.							
1 sec.	20	30	25		25	24	24
2 sec.	14	10	15		17	13	9
3 sec.	18	21	20		19	17	15
Total	52	61	60		61	54	48
		(173)				(163)	
Subjects J.P. & L.P.	95	125	109		124	105	103
		(329)				(332)	

than the numbers occurring on some of the individual trials preceding the probe. In addition, the total numbers of errors on the second trial preceding the probe for the two subjects both individually and combined are practically the same as the total numbers of errors on the first trial following. Also the total errors on the trials preceding (320) and on the trials following (332) a probe presentation for both subjects combined are not significantly different. These results, together with the chance performance levels on the one-second probe series for J.P. and on the one, two and three second probe series for L.P., would indicate that the probe trials are not only ineffective in influencing performance on the immediately following four-second foreperiod trials but are themselves, to a degree, ignored. Although there is a tendency for the number of correct identifications on the three-second probe series to approach the four-second foreperiod performance, the impressive point is, in fact, the great difference in the two performance levels. For example, the combined performance level on the probe trials for both subjects under the three-second probe series is 65 percent - if one assumes that had the subjects responded on the missed probe trials they would have gotten half of such trials correct by chance - whereas, for the four-second foreperiod trials involved in this probe series the percentage of correct identifications is in the low eighties. A one second difference in presenting the test stimuli prematurely results in approximately a twenty percent decrease in performance.

DISCUSSION

The results of Experiment II, like those obtained on the fixed foreperiod conditions of Experiment I, are clearly what one would expect had these subjects acquired an attentive strategy having its basis in the regularity inherent in the four second fixed foreperiod practice condition. The continued use of an attentional response, acquired to this temporal interval during practice, would account for the obvious superiority of the performance observed under the regular foreperiods after the subjects were shifted to a given probe series. The subjects appear to have estimated the four second foreperiod in order to be maximally attentive when they expected the regular presentation to occur. Such a "time judgement" strategy would not only account for the relatively large numbers of misses observed on the probe trials as compared to the negligible numbers observed on the four-second foreperiod trials, but also the fact that the number of misses descreased as the foreperiod length of the probe trials approached that of the anticipated four-second foreperiod.

It is interesting to note just how precisely the subjects adapted their attentive behaviour to this temporal condition. Although performance under the probe trials improved, as evidenced by increases in the number of correct responses and decreases in the number of misses as the probe foreperiod approached that of the length of the regular foreperiod, it is, even under the longest probe foreperiod vastly inferior to the performance obtained under the regular four second foreperiod.

CHAPTER FIVE

SUMMARY STATEMENTS OF RESULTS AND DISCUSSION

In this final chapter the main results of these experiments are presented as a series of brief summary statements and their implications are discussed as they relate to the development and use of attentive strategies in this and other experimental tasks, such as those of reaction time, tachistoscopic letter-sequence recognition and sensory threshold determination, in all of which various foreperiod arrangements have been studied.

Summary Statements of Results

1. Recognition performance on this tachistoscopic task is found to be influenced by three foreperiod variables in the following manner:

(a) Foreperiod length. Recognition performance under fixed foreperiods as well as the averaged performance under random foreperiods is a function of the absolute length of the foreperiod investigated. The shorter the foreperiod, the better the recognition score. This same relationship also holds for the foreperiods making up a random foreperiod when the random condition is the one first presented. When the fixed conditions are presented first, the performance curves for the foreperiods making up a random foreperiod display a well defined context effect. (Experiment I)

(b) Foreperiod variability. Performance under the fixed foreperiods is superior to that obtained under those foreperiods in the random condition having the same mean length. (Experiment I)

(c) Order of foreperiod presentation. If a subject has performed under the fixed foreperiods prior to his receiving the random condition, his performance is optimal under those foreperiods in a random set which are close to the length of the foreperiod of the preceding fixed condition and less good under both the longer and shorter foreperiod lengths. (Experiment I)

On the other hand, when the random foreperiod condition precedes that of the fixed, performance under the foreperiods making up the random set is related to their absolute length as in (a) above. This relationship is adequately described by a straight line. (Experiment I)

If a subject is given extensive practice under a particular fixed foreperiod prior to receiving additional numbers of these regular trials mixed with occasional foreperiods of shorter lengths, performance on such short foreperiods or probe trials is not only inferior to that obtained on the regular trials, but little different from what one would expect by chance. (Experiment II)

2. Performance under random foreperiod conditions seems unaffected by any systematic sequential effects; that is, performance on any given trial is independent of the length of the foreperiod on the trial that precedes it. (Experiment I)

3. When a small number of short foreperiod (probe) trials are randomly dispersed among regular trials with a longer fixed foreperiod, then a given probe trial:

(a) has no effect on the performance obtained on the three regular trials immediately following it.

(b) is missed completely a much greater proportion of the time than when such a trial, in the same location within the recycling sequence, is of the regular foreperiod length. The proportion of misses is inversely related to the foreperiod length of the probe.

(c) is responded to correctly more often as its length approaches that of the regular foreperiod. (Experiment II)

Discussion

The results of the experiments reported in this thesis suggest that when subjects are confronted with a situation in which the task is one initiated by a warning signal, the observed performances appear to depend upon certain experimental conditions. For example, when subjects are required to perform the recognition task under the fixed foreperiod condition, the resulting performances are suggestive of an adaptation appropriate to the inherent regularity characteristic of such a condition. On the other hand, when the subjects' first introduction to the task is such that it involves random foreperiods, the resulting performance curves suggest an adaptation appropriate to the length of the foreperiods being investigated. Although such results demonstrate that subjects can, and do, adapt in a manner appropriate to the various foreperiod conditions under which they must operate, other results also provided by these experiments indicate that subjects will sometimes demonstrate a mode of responding that is apparently more appropriate to another type of foreperiod condition other than the one they are confronted with at that time. For example, the performance of the subjects under the random foreperiods, after this condition had been preceded by the fixed condition, is surprisingly unlike that observed when the random foreperiods are the initial condition. In this case, the observed performance is not solely a function of the absolute length of the random foreperiods but similar to what one would expect had the subjects continued the mode of responding that had developed under the prior fixed condition.

In this section the author will attempt to interpret the foreperiod effects demonstrated in these experiments in terms of possible attentive strategies that subjects appear to develop when exposed to the various foreperiod conditions. Such strategies are hypothesized to be the results of a perceptual learning process involving the gradual acquisition of attentional responses to the warning interval.

In Experiment I, the data obtained under the random foreperiod conditions for Group I subjects, that is, those who received this condition prior to receiving the fixed, might well be interpreted in terms of those subjects having acquired an attentive strategy like that described by the "attention-distraction" hypothesis. According to this hypothesis the subjects are assumed to be attentive with the greatest effectiveness immediately on the occurrence of the warning signal for it is assumed that as the foreperiod increases in length, the more likely it is that a distracting stimulus will have occurred during the foreperiod. That the largest number of correct identifications of the test stimuli do in fact occur under the shortest random foreperiods, is certainly in keeping with an attentive strategy in which effectiveness is determined primarily by the absolute length of the foreperiod rather than the predictability of its length from one trial to the next. Further evidence suggesting that Group I subjects had acquired an attentive strategy like that described by the "attention-distraction" hypothesis can be deduced from the performance on the individual foreperiods making up the three random foreperiod sets. The results show quite clearly that the shorter the foreperiod, the larger the number of correct identifications that are made, regardless of the mean length of the random set within which a particular foreperiod is located. This relationship between performance and foreperiod length is what one would expect had the subject adopted the strategy described above. This strategy's emphasis on length leaves no room for the context within which a foreperiod is located to have any effect on performance.

When the "attention-distraction" hypothesis was first formulated by Lake and Newbigging it was to account not only for the effects of random foreperiods on tachistoscopic recognition thresholds but for the effects of fixed foreperiods as well. This was reasonable in view of their finding that recognition thresholds under the 2.0, 4.0 and 8.0 second foreperiods of the fixed and the random conditions not only varied in the direction predicted by this hypothesis, but were also not different for a given fixed foreperiod and its corresponding random set. This was not the case, however, in my first experiment. Although the relationship between performance and foreperiod length under both the fixed and the random conditions was in the direction predicted, performance under the fixed foreperiods was found to be consistently superior to that obtained under the random foreperiods of the same mean length. This superiority of the fixed foreperiods is observed for Group II as well as Group I subjects.

It is also observed that for Group I subjects the number of correct identifications made under a fixed foreperiod of a given length was larger than the number made under a foreperiod of the same length when it was one of seven making up a random set.

This superiority of performance observed under the fixed foreperiods cannot be accounted for in terms of an attentive strategy based on the "attention-distraction" hypothesis. Since this hypothesis claims that it is the absolute length of a foreperiod on any given presentation that is crucial in determining performance and not the context in which it is contained or its predictability (regularity) from presentation to presentation.

It is the author's contention that when the foreperiod is fixed the subjects develop a different attentive strategy; one that is similar to that described in Treisman's (1958) "accuracy of time judgement" hypothesis in which subjects are assumed to make use of the warning signal as a temporal reference point in order to estimate the arrival of the critical stimulus presentation. That the subjects do indeed learn to use the regularity inherent in successive presentations of a fixed foreperiod is evidenced by a mode of responding which is maintained even when the subjects are shifted to conditions involving different foreperiod arrangements, for example, as when shifted from fixed foreperiods to random foreperiods. Evidence of this nature is derived not only from Experiments I and II, but from a reaction time study carried out by Mowrer (1940) as well.

In Experiment I, the shape of the performance curves for the seven foreperiods making up the three random foreperiods for Group II subjects differs markedly from the shape of the curves obtained for Group I subjects. Now, the Group II subjects prior to performing under these random conditions had received the fixed foreperiods. During the extensive practice which occurred on the fixed foreperiods these subjects could be assumed to have acquired on attentional response to the particular temporal intervals concerned, such that when shifted to the random conditions they still maintained this strategy of being maximally attentive on those foreperiods close in length to those foreperiods encountered under the fixed condition.

This would account for the fact that of the seven foreperiods comprising a random foreperiod set, it is the median foreperiod and the next slightly longer one which yield the largest percentages of correct identifications; in fact, the percentages of correct identifications obtained under the median foreperiods of the three random sets for the Group II subjects combined are almost identical to the percentages found when foreperiods of the same length were fixed from trial to trial. It should also be noted that the best performances of all are generally obtained, under this random condition, on the foreperiods just slightly longer than the median ones, thus indicating a slight overshoot on the part of the subject. That is, his attentiveness builds up to an optimum by the expected moment of stimulus presentation, is maintained, and then drops off. If this is the time course of attention then the finding, that those foreperiods which were shorter or longer yielded progressively poorer performances, would be predicted.

The results of Experiment II, in which subjects were given extensive practice on a 4.0 second fixed foreperiod also suggests that, in view of the poor performance on the probe trials as assessed in terms both of the numbers correct and the number of misses, the subjects did not become attentive until near the end of the foreperiod on which they had been overtrained.

Data similar in nature have also been reported for reaction time. In 1940, Mowrer carried out an experiment on reaction time in which subjects were first given practice on reaction tones at a constant interstimulus interval of 12.0 seconds. Following these preliminary practice trials, each subject received a test condition in which dispersed in a balanced random order among trials having the same constant interstimulus interval as was used in the practice condition, were eight test intervals having a range of 21 seconds (3 to 24 seconds) and differing from one another in three second steps. (This experiment has been described in detail on page 54 of the Historical Review of this thesis.) The average reaction times of all subjects on these eight test interstimulus intervals were calculated.

When reaction times were plotted as a function of the length of the interstimulus interval the resulting performance curve was very similar in shape to the three obtained when the percentages of correct identifications were plotted as a function of the length of the seven foreperiods making up each of the three random foreperiod sets, for Group II subjects. Reaction time on the 12.0 second test interval was not only the fastest, but the same as that obtained on the 12.0 second interval when it was the standard. As the test intervals varied below and above 12.0 seconds, the average reaction time increased progressively.

These results are not surprising in view of the fact that in both the tachistoscopic recognition task and the reaction time task the subject has the same requirement - to be attentive at the moment the stimulus is displayed. Newbigging (1970) has provided empirical evidence of the similarity of these tasks by showing that practice on reaction time transfers positively to tachistoscopic recognition when the same foreperiod is preserved in both tasks. It is our contention that when such tasks involve fixed foreperiods subjects learn to make use of the regularity inherent in such a situation in order to assure that they will be attentive with maximum effectiveness at the right time. The evidence cited above is meant to show that subjects do, in fact, make use of the regularity in order to anticipate the arrival of the critical stimulus and be maximally attentive at the expected moment of presentation.

Such an hypothesis accounts for the poorer performance as the length of the fixed foreperiods increases in terms of the subjects being unable to estimate the longer time intervals as accurately as the shorter intervals (Woodrow, 1930). Since the accuracy of estimation would be expected to decrease as the foreperiod length increases, the subjects are less likely to be maximally attentive at the right time on the longer foreperiods.

However, why this attentive strategy, developed under conditions where the foreperiod lengths are uniform from presentation to presentation, should result in a superior performance to that resulting from a continuously maintained attention strategy, seemly developed when a random foreperiod condition is administered first, is a question for which there is no empirical answer. Thus, the following attempt at providing an answer is of necessity highly speculative.

It may well be that under the extensive practice provided on a given fixed foreperiod, the attentional response becomes very strongly conditioned to the temporal interval, such that, as soon as the expected moment of stimulus presentation occurs, the subject becomes maximally attentive. Such a highly conditioned attentive response might have one of two effects on reducing a subject's susceptibility to distraction, either of which would account for the superior performance under the fixed foreperiods. It could be that extraneous stimuli occurring within the temporal interval do, in fact, distract the subject. However, unlike in the case of the "attentional-distraction" hypothesis where a distraction is assumed to be able to disrupt attentiveness, the distraction in this case is ineffective because at the expected moment of stimulus presentation the attentional response is so strong that the subject is in effect pulled back to his task. On the other hand, one might hypothesize that somehow the effectiveness of an estimation strategy lies in reducing the capacity of an extraneous stimulus to act as a distractor. One might assume that the attentional response to the temporal interval is so strong, that is, attention becomes so strongly associated with the place the visual stimulus is to be displayed at the moment the presentation is expected, that extraneous stimuli lose their ability to attract the subject's attention. Thus, one alternative is that distracting stimuli are of no consequence to the successful performance of the task, the other is that extraneous stimuli are less likely to be distracting. As stated above, such alternative explanations at this stage are purely speculative.

In summary, it would appear that under the fixed foreperiod conditions of these experiments the subjects do develop an attentive strategy as described by the "accuracy of time judgement" hypothesis. Accordingly, the subjects learn to make use of the regularity inherent in this foreperiod condition in order to be maximally attentive at the expected moment of stimulus presentation. However, probably the most interesting finding was that upon being shifted to the random conditions, as were the Group II subjects in Experiment I, or placed in a probe situation, as were the subjects in Experiment II, these subjects continued to use this previously learned strategy by anticipating those foreperiods which were of the same length as those upon which they had received so much prior practice under the fixed foreperiod condition.

This fact, that what is learned under prior fixed foreperiod conditions might influence performance under the random foreperiod conditions, is not only an important one, but one which has generally been ignored by investigators of foreperiod effects. This has fostered attempts to explain the shape of the performance curves obtained under the random conditions in terms of the sequential effects of preceding foreperiod lengths. Karlin (1959), for example, carried out an experiment in which he observed the effect on reaction time of 0.5, 1.0, 2.0 and 3.5 second fixed and random foreperiods. Each of the random foreperiods comprised three foreperiods; the median foreperiod corresponded to one of the foreperiods of the constant condition, while the other two foreperiods were either 20% above or 20% below this median. Karlin analysed the reaction times obtained on each of the three foreperiods making up a random foreperiod condition and reported that the shortest foreperiod yielded the slowest RTs, whereas, the median and longest foreperiods yielded the fastest reactions. Karlin then attempted to explain the resulting curves in terms of the effect upon reaction time of the length of the immediately preceding foreperiods. He postulated, as did Klemmer (1956) that if a short foreperiod were preceded by a long one, the subject is likely to be caught "napping" and this would have an adverse effect upon RT. On the other hand, a long foreperiod preceded by a short one should yield faster RTs, since the subject, influenced by the short foreperiod, would get ready more quickly and stay ready longer. In this way, the consistently longer RTs obtained under the shortest foreperiods of the random foreperiods might be due to the fact that the shortest foreperiod was preceded more often by the longer foreperiods.

However, a closer look at Karlin's performance curves reveals that they have features which, in view of the results of the experiments reported in this thesis, suggest that their shape might be accounted for, at least in part, in terms of what was learned on the fixed foreperiods. First, out of a total of eight curves[1] three had the fastest reaction times occurring on trials with the median foreperiods. Secondly, the RTs obtained on these median foreperiods were very similar to the RTs obtained on the corresponding fixed foreperiods. For example, in the first experiment carried out by Karlin the median foreperiods of 1.0, 2.0 and 3.0 seconds yielded RTs of 256, 273, and 274 milliseconds respectively, as compared to the respective fixed RTs of 256 millisec., 271 millisec., and 280 milliseconds.

These features of the performance curves are very similar to the features of the performance curves for the seven foreperiods making up each of the random foreperiods obtained from Group II subjects in Experiment I of this thesis. These subjects had received the fixed foreperiods prior to the random conditions. From Karlin's Procedure

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1. Karlin repeated the original experiment changing only the duration of the warning tone from 0.1 sec. down to .03 sec. and increasing its intensity from 33 db up to 49 db.

Section it can be noted that four subjects received the foreperiod conditions in the order, FRFRF, and the remaining four in the order, RFRFR. Thus it may well be that under the fixed foreperiods the subjects had learned to make use of the regularity inherent in this condition in order to be maximally attentive at the moment of the reaction stimulus, and that when shifted to the random condition continued to use this strategy. As a result performance on the median foreperiods would be close to that obtained on the corresponding fixed foreperiods whereas performance on the shortest and longest foreperiods would tend to be poorer than the performance on this median foreperiod. In fact, the superior performance that sometimes occurs on the longest of the foreperiods, the one immediately longer than the median, could be accounted for if it were assumed that due to a subject's inability to estimate the median foreperiod length precisely, he tends to maintain his high degree of attentiveness until he is satisfied the median foreperiod is over. The point is, however, that while Karlin has attempted to account for such performance curves in terms of expectancies set up during successive presentations of the varying foreperiods, another interpretation is at least possible. It is that learning on one type of foreperiod condition may have influenced the manner in which a subject performed on the other type of foreperiod.

On the other hand, considering some of the results of these experiments and those of others reviewed in this thesis, there seems good reason to believe that attentive behaviour is, in many cases, adaptive to the particular foreperiod conditions under which a subject must operate. Indeed, if attentional responses are to be considered, as Newbigging (1965) has proposed, the mechanism which mediates the changes in stimulus-response correlations observed in judgemental tasks they would of necessity have to be adaptive in order to account for the facts of perceptual learning and transfer. In the two experiments presented in this thesis, the performance on the tachistoscopic recognition task employed would suggest that subjects do learn to make use of the regularity inherent in a fixed foreperiod situation so as to be maximally attentive at the expected moment of test stimulus presentation. Likewise, if subjects are presented with a randomly varying foreperiod situation as their first introduction to foreperiods, their performance would suggest the adoption of a different attentive strategy, one of being attentive from the occurrence of the warning signal until the test stimulus to be recognized is presented.

The problem is, as stated elsewhere in this discussion, that when the subjects are shifted from a fixed foreperiod situation to a random foreperiod situation they appear to retain their old strategy of attempting to estimate those foreperiods of the randomization which are close to those foreperiods experienced under the prior fixed condition. Why such a time judgement strategy is retained is, at this point, a matter of speculation. However, part of the answer may be that during the fixed foreperiod practice attentional responses becomes very strongly conditioned to the relevant temporal intervals such that when confronted with the random foreperiod condition the subject, rather than expend the additional effort assumed to be required in order to attend over the entire range of foreperiods of a random condition, is content merely to anticipate those intervals close to those on which he has had so much prior practice.

Regarding attention from this point of view it would be important to obtain information as to how precise this adaptation of the attentional response is. Such information might, for example, be obtained from noting changes in the shape of the performance curves as the foreperiods making up a random set are moved closer around a prior practiced fixed foreperiod. Instead of 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, and 5.5 second foreperiods one might use 3.7, 3.8, 3.9, 4.0, 4.1, 4.2, and 4.3 second foreperiods. One might also gain information of how this precision is built up by varying the amount of practice a subject receives on a prior fixed foreperiod. It is questions such as these which may serve to guide further research on the role of attentive strategies in tasks initiated by a warning signal.

APPENDICES

APPENDIX A

DATA FOR EXPERIMENT I

The Following Tables Present the Number of Correct Identifications made by Each of the Group I Subjects, G.S., W.S., B.S. and R.S. from Session to Session on each of the One-half, One, Two and Four Second Fixed Foreperiods.

The Number of Correct Identifications per Session made by G.S. on each of the Four FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)			
		.5	1	2	4
1	.5-1-2-4	72	64	61	60
2	2-.5-1-4	81	89	90	80
3	2-1-4-.5	73	68	68	65
4	1-2-4-.5	71	81	80	61
5	4-.5-1-2	78	78	77	72
6.	4-1-2-.5	76	74	68	62
7	4-2-.5-1	81	71	66	61
8	2-1-.5-4	80	72	71	64
9	1-4-.5-2	82	84	80	79
10	2-4-1-.5	85	77	75	64
11	4-1-.5-2	83	76	68	64
12	.5-1-2-4	89	83	80	67
13	4-.5-2-1	86	81	78	70
14	4-2-.5-1	70	66	68	57
15	.5-4-1-2	92	86	79	75
TOTAL (1500)		1202	1150	1109	1001
Percentage		80%	77%	74%	67%

(3) (3) (7)

The Number of Correct Identifications per Session made by W.S. on each of the Four FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds) .5	1	2	4
1	2-1-.5-4	89	87	86	77
2	4-1-2-.5	89	88	87	79
3	.5-1-4-2	87	88	87	87
4	1-2-4-.5	94	90	85	78
5	4-2-1-.5	98	96	92	90
6	1-2-.5-4	90	88	86	81
7	2-.5-4-1	97	96	94	89
8	1-.5-4-2	94	90	87	83
9	.5-1-2-4	91	89	86	83
10	4-2-1-.5	92	87	83	70
TOTAL (1000)		921	899	873	817
Percentage		92%	90%	87%	82%
			(2)	(3)	(5)

The Number of Correct Identifications per Session made by B.S. on each of the Four FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds) .5	1	2	4
1	4-2-1-.5	79	76	76	67
2	4-2-1-.5	85	85	83	76
3	.5-1-2-4	84	78	75	69
4	.5-1-2-4	90	85	77	72
5	2-.5-4-1	82	79	68	60
6	1-.5-4-2	95	85	77	73
7	1-.5-2-4	79	76	71	66
8	.5-1-4-2	88	82	72	61
9	4-2-1-.5	89	79	77	68
10	.5-1-2-4	76	70	65	60
11	1-4-2-.5	86	82	75	74
12	2-1-.5-4	82	78	69	61
13	2-4-.5-1	88	84	77	66
14	.5-2-4-1	92	87	83	79
TOTAL (1400)		1195	1126	1045	952
Percentage		85%	80%	75%	68%

(5) (5) (7)

The Number of Correct Identifications per Session made by R.S. on each of the Four FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)			
		.5	1	2	4
1	4-1-.5-2	79	79	73	67
2	4-1-.5-2	84	72	70	61
3	.5-1-2-4	76	69	66	57
4	.5-1-2-4	70	68	62	55
5	4-2-1-.5	85	74	69	61
6	1-.5-2-4	77	71	66	59
7	2-4-1-.5	72	72	70	63
8	1-.5-2-4	79	70	65	65
9	1-2-4-.5	81	74	68	55
10	4-2-1-.5	78	73	63	60
11	2-4-1-.5	81	76	69	68
12	4-1-.5-2	76	72	64	53
13	2-4-.5-1	78	68	63	57
14	2-4-.5-1	71	72	65	61
15	.5-4-2-1	79	75	71	65
TOTAL (1500)		1166	1085	1004	907
Percentage		78%	72%	67%	60%
			(6)	(5)	(7)

The Following Tables Present the Number of Correct Identifications made by Each of the Group II Subjects, J.B., S.B., A.B. and A.A. from Session to Session on each of the Two, Four and Eight Second Fixed Foreperiod.

The Number of Correct Identifications per Session made by J.B. on each of the Three FIXED Foreperiod Conditions. Each session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)		
		2	4	8
1	4-2-8	75	74	55
2	8-2-4	89	70	55
3	4-2-8	81	69	57
4	8-4-2	76	72	59
5	4-2-8	79	73	67
6	4-2-8	83	74	69
7	4-8-2	86	77	67
8	2-4-8	81	76	60
9	2-8-4	84	75	66
10	2-8-4	79	72	63
11	2-8-4	81	74	56
12	2-4-8	72	68	62
13	8-4-2	72	74	68
14	8-2-4	75	69	65
TOTAL (1400)		1113	1017	869
Percentage		80%	73%	62%

(7) (11)

The Number of Correct Identifications per Session made by S.B. on each of the Three FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)		
		2	4	8
1	4-2-8	85	75	71
2	4-8-2	83	68	62
3	2-4-8	89	79	67
4	2-8-4	80	62	55
5	4-8-2	88	75	65
6	8-4-2	81	78	71
7	8-4-2	86	73	62
8	4-2-8	92	82	73
9	4-8-2	89	80	78
10	2-4-8	82	74	68
11	8-2-4	88	84	71
TOTAL (1100)		943	830	743
Percentage		86%	75%	68%

(11) (7)

The Number of Correct Identifications per Session made by A.B. on each of the Three FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)		
		2	4	8
1	4-2-8	72	74	56
2	4-8-2	65	67	54
3	2-4-8	76	58	59
4	2-8-4	73	70	66
5	4-8-2	84	59	81
6	8-4-2	86	80	74
7	8-2-4	86	80	72
8	4-2-8	87	82	64
9	4-8-2	74	72	61
10	2-4-8	87	77	66
11	8-2-4	80	72	63
TOTAL (1100)		870	791	716
Percentage		79%	72%	65%

(7) (7)

The Number of Correct Identifications per Session made by A.A. on each of the Three FIXED Foreperiod Conditions. Each Session consisted of 100 Trials.

Session	Presentation Order	Number Correct Foreperiod (Seconds)		
		2	4	8
1	4-2-8	93	74	66
2	4-2-8	95	85	68
3	8-4-2	76	74	70
4	4-2-8	83	78	58
5	8-4-2	84	73	60
6	4-2-8	85	73	59
7	2-8-4	83	73	60
8	4-8-2	79	77	62
9	4-8-2	80	82	66
10	8-4-2	78	73	62
11	4-2-8	81	75	61
12	2-8-4	91	80	68
13	2-4-8	78	76	69
14	2-8-4	80	73	64
TOTAL (1400)		1166	1066	893
Percentage		83%	76%	64%

(7) (12)

The Following Tables Present the Number of Correct Identifications made by Each of the Group I Subjects, W.S., R.S., B.S. and G.S. from Session to Session on each of the Seven Foreperiods comprising Each of the One, Two, and Four Second Random Foreperiods. A Single Session consisted of Fourteen Presentations on Each of these Seven Foreperiods.

Number of Correct Identifications made by W.S.

One Second Random Foreperiod

Session	Foreperiods (Seconds) 0.25	0.5	0.75	1.0	1.25	1.5	1.75
1	11	11	11	9	5	10	9
2	11	9	9	10	11	11	9
3	11	10	10	9	8	10	9
4	8	8	11	5	7	9	11
5	12	10	14	8	13	13	10
6	9	13	14	12	11	10	14
7	10	12	11	13	10	12	8
8	10	14	9	9	12	10	10
9	10	9	9	11	11	13	12
10	12	13	10	12	12	12	12
11	12	14	9	12	13	11	8
12	10	11	11	12	10	10	12
13	13	12	12	10	9	11	13
14	13	14	13	12	13	12	10
15	14	13	14	12	11	13	11
TOTAL (1143)	166	173	167	156	156	167	158

Two Second Random Foreperiod

Session	Foreperiods (Seconds) 0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	8	10	10	10	9	10	12
2	11	10	8	9	12	8	10
3	8	9	10	8	8	11	10
4	9	9	5	10	7	11	8
5	11	11	9	12	10	11	12
6	11	11	9	13	10	11	12
7	5	8	7	10	10	11	10
8	9	12	11	11	11	11	6
9	10	11	9	12	11	10	12
10	12	12	10	10	10	9	11
11	9	11	8	10	11	6	11
12	11	12	10	11	12	12	9
13	13	12	12	12	6	11	10
14	13	13	12	12	12	11	12
15	14	13	13	12	12	12	10
TOTAL (1084)	154	164	143	162	151	155	155

Number of Correct Identifications made by W.S. (cont'd)

Four Second Random Foreperiod

Session	Foreperiods (Seconds) 2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	6	10	8	8	10	9	7
2	10	10	10	8	11	8	9
3	11	11	9	8	8	10	6
4	9	9	3	7	8	8	9
5	10	12	9	11	8	10	11
6	12	8	10	10	11	10	10
7	8	9	10	9	6	6	11
8	11	9	10	11	9	9	7
9	10	11	11	8	11	7	12
10	11	7	12	10	9	12	7
11	10	9	9	10	6	5	6
12	8	9	11	12	7	9	7
13	11	10	11	8	10	11	9
14	11	10	13	10	11	9	12
15	10	11	8	11	8	11	12
TOTAL (980)	148	145	144	141	133	134	135

Number of Correct Identifications made by R.S.

One Second Random Foreperiod

Session	Foreperiods (Seconds) 0.25	0.5	0.75	1.0	1.25	1.5	1.75
1	12	13	6	9	10	10	10
2	14	12	11	11	9	11	10
3	11	12	12	9	11	11	9
4	13	10	9	9	9	10	10
5	12	14	9	7	13	9	9
6	13	10	12	12	9	9	8
7	10	12	14	10	7	12	7
8	10	12	11	10	7	7	9
9	11	13	12	10	8	7	8
10	12	12	11	10	7	9	10
11	13	12	10	8	6	9	9
12	10	11	10	9	9	10	9
13	12	10	12	11	8	8	8
14	12	12	11	9	10	10	12
15	10	12	9	10	9	11	8
TOTAL (1066)	175	177	159	144	132	143	136

Number of Correct Identifications made by R.S. (cont'd)

Two Second Random Foreperiod

Session	Foreperiods (Seconds)						
	0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	11	9	11	7	9	10	7
2	11	12	12	10	7	9	10
3	10	8	10	11	12	11	9
4	12	10	7	8	9	9	9
5	11	12	10	7	9	9	7
6	11	10	14	8	5	7	8
7	10	11	9	9	8	11	8
8	12	11	9	10	8	7	5
9	9	12	10	8	8	8	8
10	9	13	10	6	6	10	6
11	10	11	9	12	9	7	8
12	12	11	8	10	8	8	8
13	11	11	10	5	9	7	7
14	10	7	12	8	10	8	8
15	9	12	10	7	9	9	7
TOTAL (966)	158	160	151	126	126	130	115

Four Second Random Foreperiod

Session	Foreperiods (Seconds)						
	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	10	7	8	8	8	6	7
2	12	9	10	8	10	8	9
3	12	8	11	9	9	8	7
4	7	10	6	10	9	6	6
5	9	10	8	8	7	5	7
6	8	9	11	5	9	6	6
7	12	8	8	8	7	5	5
8	10	7	7	8	6	7	6
9	9	10	7	5	5	4	6
10	9	10	9	8	5	8	9
11	10	9	9	7	9	8	8
12	9	9	6	9	7	6	8
13	8	7	6	7	6	8	7
14	10	9	7	8	10	8	8
15	9	9	7	8	8	6	7
TOTAL (831)	144	131	120	116	115	99	106

Number of Correct Identifications made by B.S.

One Second Random Foreperiod

Session	Foreperiods (Seconds) 0.25	0.5	0.75	1.0	1.25	1.5	1.75
1	11	11	12	11	9	9	9
2	12	12	12	10	8	12	11
3	12	13	11	11	10	10	8
4	13	10	13	8	9	8	10
5	13	10	10	9	8	7	8
6	11	10	10	10	8	10	8
7	12	12	12	9	6	7	9
8	12	13	11	9	9	9	10
9	12	12	12	10	8	7	8
10	12	12	11	11	12	11	9
11	12	12	7	10	9	7	7
12	11	12	10	9	10	7	9
13	12	9	11	10	7	9	8
14	11	11	8	10	8	6	8
15	12	13	11	9	7	8	8
TOTAL (1043)	178	173	161	146	128	127	130

Two Second Random Foreperiod

Session	Foreperiods (Seconds) 0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	10	7	8	10	9	9	10
2	12	12	9	8	9	11	8
3	12	11	10	11	7	8	8
4	11	11	8	9	8	9	7
5	12	9	11	9	6	7	8
6	10	10	7	11	7	7	11
7	11	11	8	11	12	7	6
8	11	13	11	9	9	8	8
9	12	12	10	11	6	4	9
10	10	13	11	10	10	9	10
11	11	9	8	10	12	7	6
12	11	11	10	11	8	5	7
13	11	11	11	8	8	7	7
14	10	10	9	4	9	9	8
15	6	12	11	11	10	5	7
TOTAL (969)	160	162	142	143	130	112	120

Number of Correct Identifications made by B.S. (cont'd)

Four Second Random Foreperiod

Session	Foreperiods (Seconds)						
	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	8	8	9	6	7	4	7
2	10	11	12	8	8	7	7
3	10	7	10	7	8	7	8
4	7	6	8	6	8	6	7
5	9	9	7	8	9	6	8
6	9	9	7	7	5	6	7
7	10	7	12	7	6	4	8
8	10	6	11	9	9	7	7
9	11	8	12	6	4	7	6
10	10	12	11	9	8	9	9
11	9	8	8	8	8	6	6
12	11	11	11	9	8	7	8
13	11	11	9	9	8	7	7
14	10	9	9	5	7	5	6
15	10	10	5	5	7	6	7
TOTAL (836)	145	131	141	107	110	94	108

Number of Correct Identifications made by G.S.

One Second Random Foreperiod

Session	Foreperiods (Seconds)						
	0.25	0.5	0.75	1.0	1.25	1.5	1.75
1	10	8	10	11	9	8	10
2	9	8	10	9	9	9	10
3	8	5	7	8	9	5	10
4	8	10	9	6	6	5	7
5	10	14	9	11	10	10	10
6	11	9	13	9	9	11	9
7	12	12	13	10	12	12	10
8	12	11	7	7	8	10	9
9	11	7	7	9	8	10	6
10	13	9	8	7	9	10	11
11	8	12	10	9	9	8	6
12	8	12	12	10	8	7	9
13	12	11	11	8	10	10	5
14	9	7	11	9	10	6	7
15	11	11	14	10	11	99	10
TOTAL (1056)	164	159	162	142	148	141	140

Number of Correct Identifications made by G.S. (cont'd)

Two Second Random Foreperiods

Session	0.5	1.0	1.5	2.0	2.5	3.0	3.5
	Foreperiods (Seconds)						
1	6	10	11	10	10	10	10
2	12	6	11	10	7	12	9
3	11	7	7	10	11	6	7
4	9	8	7	11	9	8	8
5	11	5	10	7	11	9	9
6	8	9	11	9	10	11	11
7	14	12	12	10	10	9	5
8	9	8	7	8	12	10	9
9	11	9	10	7	7	6	9
10	9	8	7	9	10	11	8
11	7	8	10	10	11	11	10
12	12	9	8	8	8	8	10
13	11	7	12	9	8	7	8
14	7	8	10	9	6	10	6
15	12	11	11	11	9	12	10
TOTAL (1042)	159	137	155	510	150	152	139

Four Second Random Foreperiod

Session	2.5	3.0	3.5	4.0	4.5	5.0	5.5
	Foreperiods (Seconds)						
1	8	10	10	8	5	7	8
2	8	10	11	8	9	9	5
3	8	6	13	10	9	5	9
4	6	4	7	6	6	7	5
5	10	9	10	7	10	9	6
6	11	9	10	10	8	9	4
7	10	12	11	11	8	8	11
8	8	12	7	9	6	8	8
9	4	6	8	4	8	8	8
10	10	8	10	6	8	7	7
11	6	10	5	6	8	10	7
12	7	11	8	10	6	7	10
13	8	10	9	8	6	8	7
14	9	6	6	6	6	7	7
15	10	11	9	10	8	12	7
16	11	11	10	9	9	6	11
TOTAL (918)	134	145	144	128	120	127	120

The Following Tables Present the Number of Correct Identifications made by Each of the Group II Subjects, J.B., S.B., A.A. and A.B. from Session to Session on each of the Seven Foreperiods comprising Each of the Two, Four, and Eight Second Random Foreperiods. A Single Session consisted of Fourteen Presentations on Each of these Seven Foreperiods.

Number of Correct Identifications made by J.B.

Two Second Random Foreperiod

Session	Foreperiods (Seconds) 0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	10	8	9	10	8	8	10
2	9	9	10	10	11	10	10
3	8	6	9	12	12	7	7
4	6	8	8	12	12	8	6
5	8	8	10	12	13	8	8
6	8	8	10	13	13	7	8
7	8	10	10	10	12	9	8
8	8	9	10	11	12	10	6
9	7	8	10	12	12	9	7
10	8	9	12	12	7	9	8
11	9	7	10	11	13	9	9
12	10	9	10	10	12	8	8
13	9	10	9	11	10	9	10
14	9	9	9	11	12	10	8
TOTAL (922)	117	118	136	157	160	121	113

Four Second Random Foreperiod

Session	Foreperiods (Seconds) 2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	8	7	10	9	10	6	7
2	7	9	10	11	7	7	7
3	7	6	7	11	11	8	5
4	7	8	7	11	10	6	5
5	8	7	11	11	9	9	8
6	7	7	9	12	12	6	6
7	7	7	9	11	11	7	7
8	8	7	9	10	9	9	7
9	7	7	10	11	11	6	8
10	7	8	10	11	10	7	8
11	8	9	9	10	10	8	6
12	9	7	9	11	10	7	9
13	8	7	8	10	12	10	7
14	7	8	11	10	10	8	9
TOTAL (832)	105	104	129	149	142	104	99

Number of Correct Identifications made by J.B. (cont'd)

Eight Second Random Foreperiod

Session	Foreperiods (Seconds)						
	6.5	7.0	7.5	8.0	8.5	9.0	9.5
1	7	7	6	7	7	6	7
2	6	6	6	7	7	6	7
3	5	6	7	10	11	4	7
4	7	7	6	8	10	5	5
5	6	7	9	10	11	8	6
6	6	6	9	11	11	6	6
7	6	6	9	9	8	6	6
8	6	7	6	10	8	7	6
9	7	7	8	10	9	8	7
10	8	6	5	10	11	6	8
11	8	4	8	8	8	9	7
12	7	8	8	10	10	7	6
13	8	5	7	9	9	9	7
14	8	9	7	10	9	6	6
TOTAL (729)	95	91	101	129	129	93	91

Number of Correct Identifications made by S.B.

Two Second Random Foreperiod

Session	Foreperiods (Seconds)						
	0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	11	10	13	9	11	13	7
2	8	13	12	12	13	10	11
3	8	10	8	12	10	10	12
4	12	11	12	10	11	8	8
5	10	11	13	13	13	11	11
6	11	12	12	11	13	12	8
7	8	8	12	8	13	12	11
8	12	10	11	12	13	12	11
9	10	7	14	8	13	13	9
10	10	10	12	9	12	12	14
TOTAL (762)	100	102	119	104	122	113	102

Number of Correct Identifications made by S.B. (cont'd)

Four Second Random Foreperiod

Session	Foreperiods (Seconds) 2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	10	11	10	11	12	8	6
2	10	12	10	13	13	9	10
3	8	10	8	11	13	9	8
4	5	11	10	10	13	6	11
5	9	8	11	12	13	11	10
6	9	10	12	11	13	9	11
7	9	11	9	11	13	5	10
8	10	10	10	14	10	12	12
9	10	7	10	11	11	9	8
10	9	11	11	12	12	12	9
TOTAL (715)	89	101	101	116	123	90	95

Eight Second Random Foreperiod

Session	Foreperiods (Seconds) 6.5	7.0	7.5	8.0	8.5	9.0	9.5
1	6	8	13	10	12	9	7
2	10	10	9	11	11	9	7
3	9	9	10	10	11	8	6
4	6	5	7	12	10	9	8
5	8	9	7	12	11	9	7
6	8	9	12	8	11	9	7
7	5	8	10	10	12	5	7
8	7	10	13	10	12	8	7
9	6	12	8	8	8	10	7
10	9	12	6	12	11	9	7
TOTAL (628)	74	92	95	103	109	85	70

Number of Correct Identifications made by A.A.

Two Second Random Foreperiod

Session	Foreperiods (Seconds)						
	0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	8	7	12	13	12	10	10
2	10	10	11	14	12	9	6
3	5	8	12	11	13	9	10
4	9	8	11	12	12	9	7
5	8	7	7	10	13	7	7
6	6	9	12	12	12	9	5
7	7	8	8	11	12	10	6
8	8	10	9	12	12	9	10
9	9	10	11	11	12	8	9
10	9	8	12	11	11	7	11
11	9	8	9	12	10	10	8
12	10	11	8	11	10	8	9
13	7	11	10	11	10	7	7
14	5	12	13	10	7	11	6
15	10	7	11	8	7	12	9
TOTAL (999)	120	134	156	169	165	135	120

Four Second Random Foreperiod

Session	Foreperiods (Seconds)						
	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	10	9	12	10	12	8	9
2	10	7	8	11	11	7	11
3	6	10	10	10	10	6	6
4	6	8	8	12	12	9	6
5	6	8	8	8	11	9	6
6	8	9	10	11	12	6	5
7	6	9	8	10	10	6	7
8	8	9	10	12	11	6	7
9	8	8	7	11	11	12	9
10	6	8	9	12	13	7	9
11	9	7	8	9	13	8	6
122	7	6	9	11	10	7	11
13	8	7	7	12	12	8	6
14	9	4	11	8	7	10	9
15	8	9	11	8	8	6	9
TOTAL (916)	115	118	136	155	163	113	116

Number of Correct Identifications Made by A.A. (cont'd)

Eight Second Random Foreperiod

Session	Foreperiods (Seconds)						
	6.5	7.0	7.5	8.0	8.5	9.0	9.5
1	9	5	7	7	8	7	9
2	5	9	10	9	10	8	10
3	7	6	8	9	10	4	7
4	7	5	9	10	8	6	7
5	6	6	6	9	10	7	6
6	9	7	9	12	9	5	7
7	8	4	10	9	5	8	5
8	5	7	10	10	9	8	10
9	8	8	9	9	6	8	7
10	7	7	9	11	9	7	8
11	7	7	9	9	10	6	5
12	8	7	6	7	12	8	7
13	7	6	9	10	10	6	7
14	8	9	8	5	7	7	10
15	9	7	4	6	10	8	6
TOTAL (812)	110	100	123	132	133	103	111

Number of Correct Identifications made by A.B.

Two Second Random Foreperiod

Session	Foreperiods (Seconds)						
	0.5	1.0	1.5	2.0	2.5	3.0	3.5
1	13	8	12	12	10	7	9
2	11	12	10	9	11	9	7
3	8	14	9	8	10	9	12
4	7	10	9	8	8	10	7
5	10	10	10	12	10	9	12
6	7	7	9	6	9	13	9
7	10	7	7	11	7	10	10
8	11	10	9	12	8	6	10
9	8	7	11	9	11	12	11
10	11	9	10	8	10	11	7
TOTAL (665)	96	94	96	95	94	96	94

Number of Correct Identifications made by A.B. (cont'd)

Four Second Random Foreperiod

Session	Foreperiods (Seconds)						
	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1	8	12	8	10	14	7	8
2	9	10	10	10	13	7	7
3	5	10	8	10	9	9	11
4	6	7	10	10	9	8	8
5	11	7	10	7	8	10	7
6	11	7	10	6	10	9	10
7	8	8	8	12	9	12	10
8	8	8	9	12	7	9	8
9	9	8	7	8	7	7	6
10	9	10	10	9	13	6	7
TOTAL (620)	84	87	90	94	99	84	82

Eight Second Random Foreperiod

Session	Foreperiods (Seconds)						
	6.5	7.0	7.5	8.0	8.5	9.0	9.5
1	12	9	9	10	8	5	13
2	7	8	10	8	7	11	5
3	8	9	6	11	9	8	10
4	7	7	9	6	8	5	6
5	5	9	9	10	9	8	9
6	4	7	8	9	11	9	7
7	8	12	9	5	9	10	6
8	9	7	8	10	10	10	9
9	8	9	8	9	9	9	8
10	6	8	11	8	9	6	7
TOTAL (582)	74	85	87	86	89	81	80

Results of the Chi-Square Tests on Various Foreperiod Comparisons made under both Fixed and Random Conditions by the Individual Subjects Comprising Groups I and II.

Group I Subjects	Comparisons Made	Fixed		Random	
		df	P	df	P
	0.5 sec. - 1.0 sec.	1	.06NS		
W.S.	1.0 sec. - 2.0 sec.	1	.06NS	1	.02
	2.0 sec. - 4.0 sec.	1	.001	1	.001
	0.5 sec. - 1.0 sec.	1	.001		
R.S.	1.0 sec. - 2.0 sec.	1	.01	1	.001
	2.0 sec. - 4.0 sec.	1	.001	1	.001
	0.5 sec. - 1.0 sec.	1	.05		
G.S.	1.0 sec. - 2.0 sec.	1	.06NS	1	NS
	2.0 sec. - 4.0 sec.	1	.001	1	.001
	0.5 sec. - 1.0 sec.	1	.01		
B.S.	1.0 sec. - 2.0 sec.	1	.001	1	.01
	2.0 sec. - 4.0 sec.	1	.001	1	.001

Group II Subjects	Comparisons Made	Fixed		Random	
		df	P	df	P
A.A.	2.0 sec. - 4.0 sec.	1	.001	1	.01
	4.0 sec. - 8.0 sec.	1	.001	1	.001
A.B.	2.0 sec. - 4.0 sec.	1	.001	1	.05
	4.0 sec. - 8.0 sec.	1	.001	1	.06NS
S.B.	2.0 sec. - 4.0 sec.	1	.001	1	.02
	4.0 sec. - 8.0 sec.	1	.001	1	.001
J.B.	2.0 sec. - 4.0 sec.	1	.001	1	.001
	4.0 sec. - 8.0 sec.	1	.001	1	.001

APPENDIX B

DATA FOR EXPERIMENT II

The Number of Correct Identifications made from Session to Session by J.P. on 1100 Four Second Fixed Foreperiod Trials of Practice I. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequency.

Session	Random Sequence	Number Correct on Four Second Foreperiod: Regular Trial Position N = 1045	Number Correct on Four Second Foreperiod: "Probe Trial" Position N = 55
1	4A	60	3
	4B	67	2
2	1A	63	3
	1B	65	4
3	2A	61	4
	2B	63	1
4	2A	60	3
	2B	64	4
5	3A	66	4
	3B	70	5
6	1B	73	4
TOTAL		712	37
Percent		68%	67%

The Number of Correct Identifications made from Session to Session by J.P. on 1000 Four Second Fixed Foreperiod Trials of Practice II. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequence.

Session	Random Sequence	Number Correct on Four-Second Foreperiod	
		Regular Trial Position N = 950	"Probe Trial" Position N = 50
1	1A	75	4
	1B	75	4
2	1A	73	2
	1B	77	3
3	4A	74	5
	4B	78	3
4	2A	74	4
	2B	75	5
5	3A	70	5
	3B	78	4
TOTAL		749	39
Percent		79%	78%

The Number of Correct Identifications made from Session to Session by J.P. on 1100 Four Second Fixed Foreperiod Trials of Practice III. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequence.

Session	Random Sequence	Number Correct on Four-Second Foreperiod	
		Regular Trial Position N = 1045	"Probe Trial" Position N = 55
1	1A	76	2
	1B	82	4
2	1A	78	4
	1B	81	4
3	2A	82	5
	2B	80	4
4	3A	81	3
	3B	80	5
5	4A	84	5
	4B	78	4
6	1A	81	5
TOTAL		883	45
Percent		84%	82%

The Number of Correct Identifications made from Session to Session by L.P. on 800 Four Second Fixed Foreperiod Trials of Practice I. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequence.

Session	Random Sequence	Number Correct on Four-Second Foreperiod	
		Regular Trial Position N = 760	"Probe Trial" Position N = 40
1	2A	66	4
	2B	71	3
2	1A	67	3
	1B	80	5
3	3A	58	3
	3B	62	3
4	4A	71	4
	4B	74	4
TOTAL		549	29
Percent		72%	73%

The Number of Correct Identifications made from Session to Session by L.P. on 1000 Four Second Fixed Foreperiod Trials of Practice II. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequence.

Session	Random Sequence	Number Correct on Four-Second Foreperiod	
		Regular Trial Position N = 950	"Probe Trial" Position N = 50
1	4A	73	2
	4B	83	5
2	2A	73	4
	2B	74	5
3	3A	73	4
	3B	86	4
4	1A	78	4
	1B	82	5
5	3A	78	4
	3B	85	5
TOTAL		785	42
Percent		83%	84%

The Number of Correct Identifications made from Session to Session by L.P. on 1000 Four Second Fixed Foreperiod Trials of Practice III. Each Session consisted of 200 Trials. The Column Headed "Probe Trials" gives Data for those Four Second Trials which occupy a Probe Position in a Particular Random Sequence.

Session	Random Sequence	Number Correct on Four-Second Foreperiod	
		Regular Trial Position N = 950	"Probe Trial" Position N = 50
1	1A	87	5
	1B	82	4
2	2A	81	4
	2B	79	4
3	3A	69	5
	3B	78	4
4	2A	75	5
	2B	77	4
5	4A	71	2
	4B	67	3
TOTAL		766	40
Percent		81%	80%

The Number of Correct Identifications made from Session to Session by J.P. on 2850 Four Second Fixed Foreperiod Trials and on 150 One Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct One Second Probe
1	1A	72	1
	1B	71	0
2	2A	70	2
	2B	76	0
3	3A	80	1
	3B	69	3
4	4A	73	1
	4B	72	1
5	1A	75	1
	1B	70	3
6	4A	71	1
	4B	73	0
7	2A	70	2
	2B	76	2
8	4A	73	2
	4B	75	1
9	3A	69	3
	3B	71	3
10	2A	73	2
	2B	65	3
11	1A	71	1
	1B	70	1
12	2A	74	1
	2B	79	0
13	3A	81	3
	3B	66	3
14	1A	72	2
	1B	76	3
15	4A	73	1
	4B	75	2
TOTAL		2181	49
Percent		77%	33%

The Number of Correct Identifications made from Session to Session by J.P. on 1425 Four Second Fixed Foreperiod Trials and on 75 Two Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct Two Second Probe
1	1A	79	3
	1B	65	4
2	3A	78	1
	3B	75	5
3	4A	73	3
	4B	81	2
4	2A	73	5
	2B	84	2
5	4A	73	3
	4B	82	2
6	2A	72	1
	2B	81	2
7	1A	77	0
	1B	76	3
8	3A	82	3
TOTAL		1151	39
Percent		81%	52%

The Number of Correct Identifications made from Session to Session by J.P. on 1520 Four Second Fixed Foreperiod Trials and on 80 Three Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct Three Second Probe
1	2A	74	4
	2B	83	4
2	3A	79	3
	3B	79	4
3	4A	77	3
	4B	84	4
4	1A	83	1
	1B	77	2
5	2A	81	3
	2B	82	4
6	3A	82	4
	3B	81	3
7	4A	76	5
	4B	78	3
8	1B	81	4
	2A	79	2
TOTAL		1276	53
Percent		84%	66%

The Number of Correct Identifications made from Session to Session by L.P. on 2470 Four Second Fixed Foreperiod Trials and on 130 One Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct One Second Probe
1	3A	69	3
	3B	75	0
2	1A	84	3
	1B	85	3
3	2A	61	1
	2B	70	2
4	1A	82	1
	1B	84	2
5	4A	82	1
	4B	80	3
6	3A	64	2
	3B	79	1
7	2A	68	2
	2B	71	3
8	4A	75	0
	4B	82	3
9	4A	74	2
	4B	75	1
10	3A	73	1
	3B	77	1
11	1A	69	1
	1B	73	2
12	1A	73	2
	1B	75	3
13	2A	61	2
	2B	79	2
TOTAL		1940	47
Percent		79%	36%

The Number of Correct Identifications made from Session to Session by L.P. on 1900 Four Second Fixed Foreperiod Trials and on 100 Two Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct Two Second Probe
1	1A	73	3
	1B	79	2
2	4A	88	2
	4B	86	2
3	3A	84	4
	3B	85	2
4	2A	75	3
	2B	80	2
5	1A	65	2
	1B	78	4
6	3A	83	3
	3B	86	1
7	1A	88	3
	1B	88	3
8	4A	81	1
	4B	92	1
9	2A	79	3
	2B	80	1
10	4A	79	3
	4B	90	3
TOTAL		1639	48
Percent		86%	48%

The Number of Correct Identifications made from Session to Session by L.P. on 1900 Four Second Fixed Foreperiod Trials and on 100 Three Second Probe Trials. Each Session consisted of 200 Trials.

Session	Random Sequence	Number Correct Four Second Foreperiod	Number Correct Three Second Probe
1	1A	76	3
	1B	74	4
2	2A	74	2
	2B	84	4
3	3A	78	3
	3B	82	3
4	4A	87	1
	4B	85	4
5	4A	72	1
	4B	74	3
6	3A	79	2
	3B	88	3
7	2A	59	2
	2B	76	1
8	1A	70	4
	1B	77	3
9	4A	64	1
	4B	70	4
10	3A	78	3
	3B	80	4
TOTAL		1527	55
		80%	55%

BIBLIOGRAPHY

Abelson, R.B. The facilitation of visual perceptual learning by saccadic eyemovement. Unpublished Ph.D. Thesis, University of Michigan, 1963 (cited by Wohlwill, 1965).

Alluisi, E.A., Morgan, B.B. and Hawke, S. Masking of cutaneous sensations in multiple stimulus presentation. Perceptual and Motor Skills, 1965, 39-45.

Bertelson, P. The time course of preparation. Quarterly Journal of Experimental Psychology, 1967, 19, 272-279.

Bertelson, P. and Renkin, A. Reaction times to new versus repeated signals in a serial task as a function of response-signal time interval. Acta Psychologica, 1966, 25, 132-136.

Bertelson, P. and Tisseyre, F. The time-course of preparation with regular and irregular foreperiods. Quarterly Journal of Experimental Psychology, 1968, 20, 297-300.

Bevan, W., Hardesty, D.L. and Avant, L.L. Response latency with constant and variable interval schedules. Perceptual and Motor Skills, 1965, 20, 969-972.

Boons, J.P. and Bertelson, P. Incertitude temporelle et reconnaissance tachistoscopique. Annee Psychologique, 1961, 61, 361-376.

Botwinick, J. and Brinley, J.F. Analysis of set in relation to reaction time. Journal of Experimental Psychology, 1962, 63, 568-574.

Botwinick, J., Brinley, J.F. and Robbin, J.S. Maintaining set in relation to motivation and age. American Journal of Psychology, 1959, 72, 585-588.

Botwinick, J. and Thompson, L.W. Premotor and motor components of reaction time. Journal of Experimental Psychology, 1966, 71, 9-15.

Breitwiesser, J.V. Attention and movement in reaction time. Archives of Psychology, 1911, No. 4 (Whole No. 18).

Bruce, R. H. and Low, F.N. The effect of practice with brief-exposure techniques upon central and peripheral visual acuity and a search for a brief test of peripheral acuity. Journal of Experimental Psychology, 1951, 41, 275-280.

Child, I.L. and Wendt, G.R. The magnitude and temporal course of facilitation of hearing by vision. Psychological Bulletin, 1936, 33, 596 (abstract).

Child, I.L. and Wendt, G.R. The temporal course of the influence of visual stimulation upon the auditory threshold. Journal of Experimental Psychology, 1938, 23, 109-127.

Chocholle, R. Les temps des reaction. (In) Fraisse P. and Piaget, J. (Ed.) Traite de Psychologie experimentale, Vol. 2, Paris: Presses universitaires de France, 1963, p. 81.

Davis, R. Set and muscular tension. Indiana University Publications, Science Series, 1940, No. 10.

Davis, R. The human operator as a single channel information system. Quarterly Journal of Experimental Psychology, 1957, 9, 119-129.

Davis, R. The role of "attention" in the psychological refractory period. Quarterly Journal of Experimental Psychology, 1959, 11, 211-220.

Drazin, D.H. Effects of foreperiod, foreperiod variability, and probability of stimulus occurrence on simple reaction time. Journal of Experimental Psychology, 1961, 62, 43-50.

Drever, James 2nd. Perceptual learning. Annual Review of Psychology, 1960, 11, 131-160.

Egan, J.P., Schulman, A.I. and Greenberg, G.Z. Memory for waveform and time uncertainty in auditory detection. Journal of the Accoustical Society of America, 1961, 33, 779-781.

Foley, P.J. The foreperiod and simple reaction time. Canadian Journal of Psychology, 1959, 13, 20-22.

Fraisse, Paul. La periode refractaire psychologique. Annee Psychologique, 1957, 57, 315-328.

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

Freeman, G.L. The optimal locus of anticipatory tensions in muscular work. Journal of Experimental Psychology, 1937, 21, 554-564.

Freeman, G.L. The optimal muscular tensions for various performances. American Journal of Psychology, 1938, 51, 146-150.

Freeman, G.L. The relationship between performance level and bodily activity level. Journal of Experimental Psychology, 1940, 26, 602-608.

Freeman, G.L. and Kendall, W.E. The effect upon reaction time of muscular tension induced at various preparatory conditions. Journal of Experimental Psychology, 1940, 27, 136-148.

Gebhard, J.W. Motokawa's studies on electric excitation of the human eye. Psychological Bulletin, 1953, 50, 73-111.

Gibson, Eleanor J. Improvement in perceptual judgements as a function of controlled practice or training. Psychological Bulletin, 1953, 50, 401-431.

Gibson, Eleanor J. Perceptual learning. Annual Review of Psychology, 1963, 14, 29-56.

Gibson, J.J. A critical review of the concept of set in contemporary experimental psychology. Psychological Bulletin, 1941, 38, 781-817.

Gibson, J.J. Perception as a function of stimulation. (In) S. Koch (Ed.), Psychology: a study of a science. Vol. 1. New York: McGraw-Hill, 1959, 456-501.

Gibson, J.J. The useful dimensions of sensitivity. American Psychologist, 1963, 18, 1-15.

Gibson, J.J. and Gibson, Eleanor J. Perceptual learning: differentiation or enrichment? Psychological Review, 1955, 62, 32-41. (a)

Gibson, J.J. and Gibson, Eleanor J. What is learned in perceptual learning? A reply to Professor Postman. Psychological Review, 1955, 62, 447-450. (b)

Gilbert, G.M. Inter-sensory facilitation and inhibition. Journal of General Psychology, 1941, 24, 381-407.

Guilford, J.P. "Fluctuations of attention" with weak visual stimuli. American Journal of Psychology, 1927, 38, 534-583.

Gulick, W.L. and Smith, F.L. The effect of intensity of visual stimulation upon auditory acuity. Psychological Record, 1959, 9, 29-32.

Hartmann, G.E. Changes in visual acuity through simultaneous stimulation of other sense organs. Journal of Experimental Psychology, 1933, 16, 393-407.

Hartmann, G.E. The facilitating effect of strong general illumination upon the discrimination of pitch and intensity differences. Journal of Experimental Psychology, 1934, 17, 813-822.

Hawickhorst, L. Mit welcher sicherkeit wird der zeitwert einer sekunde erkannt? Zeitschrift fur Sinnesphysiologie, 1934, 65, 58-66. (cited by Fraisse, 1963).

Hay, Janet M. An investigation of two determinants of the practice effect in tachistoscopic recognition: Response strength and fixation. Unpublished Ph.D. Thesis, 1963, McMaster University.

Hebb, D.O. Organization of behavior. New York: Wiley, 1949.

Hebb, D.O. Drives and the CNS (Conceptual Nervous System). Psychological Review, 1955, 62, 243-254.

Hermelin, B.M. and Venables, P.H. Reaction time and alpha blocking in normal and severely subnormal subjects. Journal of Experimental Psychology, 1964, 67, 365-372.

Hohle, R.H. Inferred components of reaction times as functions of foreperiod duration. Journal of Experimental Psychology, 1965, 69, 382-386.

Howarth, C.I. and Bulmer, M.G. Non-random sequences in visual threshold experiments. Quarterly Journal of Experimental Psychology, 1956, 8, 163-171.

Howarth, C.I. and Treisman, M. The effect of warning interval on the electric phosphene and uaditory thresholds. Quarterly Journal of Experimental Psychology, 1958, 10, 130-141.

Huston, P.E., Shakow, D. and Riggs, L.A. Studies of motor function in schizophrenia: II. reaction time. Journal of General Psychology, 1937, 16, 39-82.

James, W. Principles of psychology. (Rev. ed.) New York: Dover, 1950.

Karlin, L. Reaction time as a function of foreperiod duration and variability. Journal of Experimental Psychology, 1959, 58, 185-191.

Klemmer, E.T. Time uncertainty in simple reaction time. Journal of Experimental Psychology, 1956, 51, 179-184.

Klemmer, E.T. Simple reaction time as a function of time uncertainty. Journal of Experimental Psychology, 1957, 54, 195-200.

Kravkov, S.V. Changes of visual acuity in one eye under the influence of the illuminationoof the other or of acoustic stimuli. Journal of Experimental Psychology, 1934, 17, 805-812.

Lake, R.A. Interval effects in tachistoscopic recognition. Unpublished M.A. Thesis, 1966, McMaster University.

Lake, R.A. and Newbigging, P.L. Foreperiod effects in tachistoscopic recognition. Canadian Journal of Psychology, 1970, 24, 452-459.

Lansing, R.W., Schwartz, E. and Lindsley, D.B. Reaction time and EEG activation under alerted and nonalerted conditions. Journal of Experimental Psychology, 1959, 58, 1-7.

Lansing, R.W., Schwartz, E. and Lindsley, D.B. Reaction time and EEG activation. American Psychologist, 1956, 11, 433.

Lindsley, D.B. Emotion. (In) S.S. Stevens (Ed.), Handbook of experimental psychology. New York: Wiley, 1951, 473-516.

London, I.D. Research on sensory interaction in the Soviet Union. Psychological Bulletin, 1954, 51, 531-568.

Malmo, R.B. Activation: an neuropsychological dimension. Psychological Review, 1959, 66, 367-386.

Moruzzi, G. and Magoun, H.W. Brain stem reticular formation and activation of the EEG. Electroencephalography and Clinical Neurophysiology, 1949, 1, 455-473.

Mowrer, O.H. Preparatory set (expectancy) - some methods of measurement. Psychological Monographs, 1940, 52, (2, Whole No. 233).

Mowrer, O.H., Rayman, N.W. and Bliss, E.L. Preparatory set (expectancy) - an experimental demonstration of its "central" locus. Journal of Experimental Psychology, 1940, 26, 357-372.

Mukherjee, K. The duration of cutaneous sensation (1) and the improvement of its sensible discrimination by practice (II). Journal of Experimental Psychology, 1933, 16, 339-342.

Munoz, S.R. The effect of tone on tachistoscopic word recognition. Unpublished M.A. Thesis, McMaster University, 1963.

Munoz, S.R. and Newbigging, P.L. Some effects of an auditory ready signal on tachistoscopic word recognition. Canadian Journal of Psychology, 1970, 24 (6), 460-475.

Newbigging, P.L. The perceptual redintegration of frequent and infrequent words. Canadian Journal of Psychology, 1961, 15, 123-132.

Newbigging, P.L. Attention and perceptual learning. Canadian Psychologist, 1965, 6a, 309-331.

Newbigging, P.L. Transfer of training from reaction time to tachistoscopic recognition. Canadian Journal of Psychology, 1970, 24 (6), 476-485.

Newbigging, P.L. and Hay, Janet M. The practice effect in recognition threshold determinations as a function of word frequency and length. Canadian Journal of Psychology, 1962, 16, 177-184.

Newhall, S.M. Effects of attention on the intensity of cutaneous pressure and on visual brightness. Archives of Psychology, 1923, No. 61, 1-75.

Nickerson, R.S. and Burnham, D.W. Response times with nonaging foreperiods. Journal of Experimental Psychology, 1969, 79, 452-457.

Nickerson, R.S., Collins, A.M. and Markowitz, J. Effects of uncertain warning signals on reaction time. Perception and Psychophysics, 1969, Vol. 5 (2), 107-112.

Ogilvie, J.C. The interaction of auditory flutter and CFF: The effect of brightness. Canadian Journal of Psychology, 1956, 10, 207-210.

Ollman, R. Fast guesses in choice reaction time. Psychonomic Science, 1966, 6 (4), 155-156.

Osgood, C.E. Method and theory in experimental psychology. New York: Oxford Univer. Press, 1953.

Parker, Nora I. and Newbigging, P.L. Magnitude and decrement of the Muller-Lyer illusion as a function of pre-training. Canadian Journal of Psychology, 1963, 17, 134-140.

Pick, H.L. Perception in Soviet psychology. Psychological Bulletin, 1964, 62, 21-35.

Postman, L. Association theory and perceptual learning. Psychological Review, 1955, 62, 438-446.

Postman, L., Bronson, W.G. and Gropper, G. Is there a mechanism of perceptual defence? Journal of Abnormal and Social Psychology, 1953, 48, 215-224.

Renshaw, S. An experimental comparison of the production and auditory discrimination by absolute impression of a constant tempo. Psychological Bulletin, 1932, 29 (9), 659.

Sanders, A.F. Prewarning signal activity and RT as a function of foreperiod. Perceptual and Motor Skills, 1965, 21, 405-406.

Solomon, R.L. and Postman, L. Frequency of usage as a determinant of recognition thresholds for words. Journal of Experimental Psychology, 1952, 43, 195-201.

Stevens, S.S. (Ed.) (1951) Handbook of experimental psychology. New York: Wiley.

Teichner, W.H. Recent studies in simple reaction time. Psychological Bulletin, 1954, 51, 128, 149.

Telford, C.W. The refractory phase of voluntary and associative responses. Journal of Experimental Psychology, 1931, 14, 1-36.

Thompson, L.W. and Botwinick, J. The role of the preparatory interval in the relationship between EEG α - Blocking and reaction time. Psychophysiology, 1966, 3, 131-142.

Thompson, R.F., Voss, J.F. and Brogden, W.F. Effect of brightness of simultaneous visual stimulation on absolute auditory sensitivity. Journal of Experimental Psychology, 1958, 55, 45-50.

Treisman, M. The effect of one stimulus on the threshold for another: an application of signal detectability theory. British Journal of Statistical Psychology, 1964, 17, 15-35.

Treisman, M. and Howarth, C.I. Changes in threshold level produced by a signal preceding or following the threshold stimulus. Quarterly Journal of Experimental Psychology, 1959, 11, 129-142.

Urbantschitsch, V. Ueber den Einfluss einer Sinneserregung auf die ubrigen Sinnesempfindungen. Archiv fur die gesamte Physiologie, 1888, 42, 154-182 (cited by Gilbert, G.M., 1941).

Watkins, W.H. and Schjelderup, J.R. Effects of temporal variation of auxiliary light stimuli upon detectability of tonal signals. Perception and Psychophysics, 1967, Vol. 2 (7), 317-321.

Weiss, A.D. The locus of reaction time change with set, motivation, and age. Journal of Gerontology, 1965, 20, 60-64.

Werner, H. Musical "micro-scales" and "micro-melodies". Journal of Psychology, 1940, 10, 149-156.

Wohlwill, J.F. Perceptual learning. Annual Review of Psychology, 1966, 17, 201-231.

Woodrow, H. The measurement of attention. Psychological Monographs, 1914, 17, No. 5 (Whole No. 76).

Woodrow, H. The faculty of attention. Journal of Experimental Psychology, 1916, 1, 285-318.

Woodrow, H. The reproduction of temporal intervals. Journal of Experimental Psychology, 1930, 13, 473-499.

Woodworth, R.S. and Schlosberg, H. Experimental psychology. (Rev. ed.) New York: Holt, 1954.

Wundt, W. Grundzuge der physiologischen Psychologie. Leipzig: Engelman, Vol. II, 2nd Edition, 1880 (cited, in part, by Mowrer, O.H., 1940, and James, W., 1950).

Wyatt, Ruth F. Improvability of pitch discrimination. Psychological Monographs, 1945, 58, No. 2 (Whole No. 267).

Yellott, J.I. Correction for guessing in choice reaction time. Psychonomic Science, 1967, 8 (8), 321-322.

Zahn, T.P. and Rosenthal, D. Simple reaction time as a function of the relative frequency of the preparatory interval. Journal of Experimental Psychology, 1966, 72, 15-19.

Zietz, K. Gegenseitige Beeinflussung von Farb-und Tonerlebnissen: Studien uber experimentell erzeugte Synasthesie. Zeitschrift Fur Physiologie, 1931, 121, 257-356 (cited by Gilbert, G.M., 1941).