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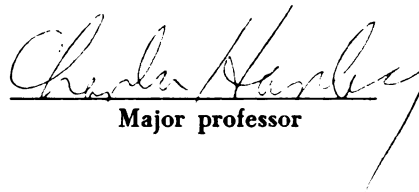
Probability Learning, Competing Responses,
and Interstimulus Interval (ISI) Effects
in Two-Choice Reaction Time

presented by

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has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Psychology


Major professor

Date December 1, 1964



ABSTRACT

The several experiments reported herein examined the phenomenon known as the Psychological Refractory Period (PRP), earlier assumed by the writer to be a special case of a "Temporary Inhibition of Response (TIR)" phenomenon (Reynolds, 1964). The behavioral manifestation of double stimulation in close temporal contiguity may, under certain conditions, be a delay in response to one of them. Exp. I & II explored this possibility under conditions of temporal certainty and event uncertainty; no evidence for the PRP was found. An attempt to train a prepotent response by means of probability learning was unsuccessful.

Exp. III used the double stimulation task with conditions of event certainty and temporal uncertainty, using either a Regular or a Random series of interstimulus intervals (ISI). The PRP was obtained; this is at some variance with previous work in tracking tasks using bisensory stimulus presentation.

Exp. IV explored the role of complete temporal and event certainty in conditions: 1) Where the S made responses to stimuli with only one ISI across all 100 trials; 2) Where the S made responses to stimuli at one ISI for 20 trials and then went on to respond to another set of stimuli at a different ISI for 20 more trials until all ISIs had been used; 3) Where the S was instructed to be equally fast with each hand in a replication of part 2) above. The PRP was obtained at shorter ISIs than in Exp. III, but only in conditions 2) and 3) above. There was no PRP in condition 1) of Exp. IV. All experiments reported herein used a unisensory (visual) task.

Results of all four experiments were thought consistent with a competing response theory of delays in response, and certain hypotheses partially testing this position were supported.

Probability Learning, Competing Responses, and Interstimulus
Interval (ISI) Effects in Two-Choice Reaction Time

by

Donald Reynolds

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Psychology

1964

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the advice and help of the members of his committee, Drs. M. Ray Denny, Chairman, Donald M. Johnson, Terence M. Allen, and Charles Hanley. It must not have been the easiest task in the world for them.

For designing and wiring the circuitry involved in these studies, special thanks go to Ronald G. Weisman and Dominic J. Zerbolio, Jr. Many hard hours of verbal and physical work by these two gentlemen resulted in smooth functioning of the equipment at a minimum strain on the E.

For figuring out visual angles, and placement of the S to insure maximum foveal stimulation, the writer is indebted to Richard Haines.

Two sympathetic shoulders to cry on when agonizing over the data and gestating reasonable theory to explain same were provided by Dr. M. Ray Denny and Ronald G. Weisman; special mention is hereby made by the writer for patience above and beyond the call of duty.

For assistance with the Lindquist Type III Analysis of Variance, thanks go to Tom Teeples and Phil Wynn, Jr. of the Statistical Services Division, HumRRO.

My wife Jeanine not only provided moral support, but proved the adage that a good wife is one who knows how to protect her husband at work. This dissertation is for that reason, and a few others, dedicated to her.

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INTRODUCTION

The general scope of the several studies reported herein deals with a phenomenon earlier labelled as the "Temporary Inhibition of Response," or the TIR phenomenon (Reynolds, 1964). This phenomenon follows from the presentation of simultaneous, or nearly simultaneous, stimuli to the subject (S). The behavioral manifestation of such double stimulation, when the S is required to respond to both, is a delay in response to one of them. The TIR phenomenon is not the result of updating the fact that a complex task requires more time than a simple one, since the delay is posited to occur in only one of the two responses. Although the whole task (making both responses) often takes more time than the two component responses combined additively, the observation that only one of the two responses is delayed may help to explain how the complex task takes more time. The TIR concept is useful because it clarifies what may be expected to occur when two stimuli follow each other in close temporal contiguity, and when response to both is required. Further, TIR provides a convenient point of departure for the comparison of different theoretical positions with respect to response output following such stimulation.

Explanations of delay in response have been advanced along traditional lines. The stimulus-centered position maintains that variation in response output is primarily related to variations in stimulus input. Organism-centered explanations take one of two customary forms: 1) "Expectancy." This position deals with the "set" of the S and tends to cognitive explanations in describing delays in response, e.g., the S is

thought to be less than optimally prepared for response when the second stimulus arrives; 2) "Central Limitation." This formulation draws sustenance more from the physiological than the cognitive realm, positing a limit on the ability of the S to respond twice in quick succession. This may be based on the belief that the first response renders the response mechanism insensitive so that it reacts more slowly to the second stimulus (Welford, 1952), or that human processing channels are analogous to a "Y-shaped funnel," down which simultaneous bits of information (or stimulation) must pass successively (Broadbent, 1957, 1958).

The third explanation, a response-centered one, calls attention to the competing response tendencies elicited by each of the stimuli in the double stimulation paradigm. Berlyne, in a somewhat different context, lays out the discussion as follows:

Instead of speaking of a conflict between two partially incompatible responses R_1 and R_2 , we might speak...of a conflict between two completely incompatible responses R_2 and R_2 , the latter being the inhibition of R_2 that is tracable to the arousal of R_1 . The greater the degree of antagonism between R_1 and R_2 , the greater the conflict, since the more nearly equal in strength R_2 and R_2 will be (1960, p. 34).

Thus Berlyne views the making of R_1 to lead to the arousal of R_2 in certain cases. If R_2 must be made anyway, it might well be delayed on the basis of arousal of competing responses. It might further be postulated that the arousal of R_2 might be diminished with practice on the task, such that a well-practiced S would not have R_2 delayed. There are two reasons for this assumption, in increasing order of importance: 1) The belief that there is no reinforcement structure to support R_2 , and 2) With repeated elicitation of R_2 , R_2 may be extinguished, since the two responses are presumed wholly incompatible.

The earlier paper (Reynolds, 1964) reviewed findings from three

apparently unrelated areas and attempted to integrate these findings as supportive evidence for the reality of the TIR phenomenon. The areas reviewed were: stereoscopic perception, dichotic listening, and two-choice reaction time. Since a historical sketch was provided of the latter, no attempt will be made herein at duplication of the same area; rather, selected studies on reaction time (RT) will be presented.

Definitions

The abbreviation "RT" will be reserved for exclusive use; it shall only refer to the direct time taken (i.e., the latency) in making a single discrete response to a single discrete stimulus. It is a pure speed measure as such, and refers to what is customarily referred to in the literature as reaction time.

Other measures of speed of response have been used by investigators. The most common of these has been called "Response Time," but such a label is confusing. The term "Response Speed" (abbreviated RS) will instead be used to refer to a speed measure in which the latency includes errors, anticipatory responses, in general any passage of time from the stimulus onset until the "correct" response has been made.

SELECTED REVIEW OF THE LITERATURE

As the interval between two stimuli becomes very short the RT to the second stimulus presented becomes lengthened as the interstimulus interval (ISI) is shortened and approaches .5 second (Adams, 1961, p. 68). This delay in response to the second stimulus at short ISIs is known as the Psychological Refractory Period (PRP). The following studies deal in common with the PRP, herein assumed to be a special case of the TIR

phenomenon. The PRP has been found to occur at ISIs of 0 milliseconds (Adams, 1962; Creamer, 1963), 50 milliseconds (Davis, 1962), 75 milliseconds (Marill, 1957), 100 milliseconds (Davis, 1956; Elithorn & Lawrence, 1955), and 500 milliseconds (Telford, 1931; Vince, 1948). The general trend seems clear: later investigators have succeeded in pushing back the point of maximum refractoriness from 500 milliseconds to at or near 0 milliseconds ISI - simultaneity of stimulus presentation. The above studies are not strictly comparable due to the different procedures used, some being bisensory and others involving unisensory tasks. In the bisensory tasks the two stimuli arrive via different modalities, the two most common being visual and auditory; in the unisensory studies only one modality is used.

Crossmodal Differences

Is the PRP confined to stimuli from the same modality, or is it general across modalities? Davis (1956) used two visual stimuli and a visual-auditory pair (1957) while varying ISIs from 50 to 400 milliseconds (1956) or 500 millisecond (1957). The pattern of results is the same with unisensory and bisensory presentation: only at the shorter ISIs did delays of response occur to the second stimulus. In a follow-up study Davis (1959) hypothesized that it is the paying of attention to a stimuli, rather than making an overt response to it, that leads to refractoriness. His results were quite complex, but were taken to show support for a "common analyzer or classifying system." Although he did not present statistics to support his conclusion, computation of t-tests from his (presented) data reveals that there is no significant difference between mean reaction times in a unisensory condition in which the S either did

or did not respond to the first stimulus ($p > .05$; two sided), but a highly significant difference when a similar comparison is made in a bisensory condition ($p < .0001$; two-sided).

The unisensory vs. bisensory finding is important. If both stimuli come in on the same modality, then whether one makes a response to both or only the second seems to make no difference in the latency of the second response, since the second response in both cases takes about the same time. But note what happens if the second modality stimulated is different from the first: the second reaction may take longer if the S has to respond to both stimuli, but not if he is only to respond to the second. In summary, then: 1) Davis' conclusions are not quite supported by his own data, as there appear to be discriminable differences between the unisensory and bisensory conditions; 2) The making of an overt response is not quite as unimportant as suggested by Davis, given the findings in the bisensory condition, and therefore the evidence for a "common analyzer or classifying system" has not been compellingly set forth; 3) One should be sensitized to the possibility of task-specificity and/or mode-specificity in the double stimulation paradigm. Such specificity has turned up in as unlikely a place as vigilance studies, in which cross-modal vigilance correlations are consistently in the vicinity of + .30 (Buckner & McGrath, 1963).

Event Uncertainty & Time Uncertainty

Early studies dealing with the PRP confounded uncertainty on the part of the S as to the event to which he was to respond (event uncertainty) with uncertainty as to the time between the two events, both of which required response (time uncertainty). To illustrate: When the S is unsure

whether the stimulus-order to which he must respond will be left-to-right or right-to-left, he is said to be in event uncertain conditions. When he knows, say, that the first stimulus will be on the right, but does not know the interval between this event and the next one on the left, he is said to be in a state of time uncertainty.

One of the first to inquire into the temporal spacing of stimulation was Klemmer (1956), who studied the effects of time uncertainty on simple (single-choice) RT. He used five different ISIs of 1 to 12 seconds in an "a-reaction" (in which the S makes a single, specified response to a single, specified stimulus) with a variable preparatory interval and found that RT tends to increase with an increase in preparatory interval variability. Since the event was certain, the increase in RT was though due to the temporal uncertainty associated with variable preparatory intervals. Recent studies have further explored the effects of time- and ovent-uncertainty in two-choice RT.

Using almost exactly the same procedure as Davis (1959), but holding temporal uncertainty to near zero by using fixed ISIs for each series of stimulus, Borger (1963) presented two stimuli to the S (auditory-visual or visual-auditory), and varied the ISI from 50 to 500 milliseconds. The second response was found to be slower when the S had to make a first response, but not so when the "second" response was the only response made. This finding held for ISIs of 300 milliseconds or less, and is in close agreement with Davis (1959) with the above noted exceptions. The subjects were very variable and statistics were not presented.

Borger felt that a theory of refractoriness based on time uncertainty was not supported by his data, since all ISIs were constant within a series. Since his stimulus-presentation was in part a bisensory one,

one should use care in accepting his interpretation. One should ideally inquire if similar results would occur given a unisensory two-choice task with only event uncertainty. Borger brought out a good point: Responses may be stored until after the second stimulus is received, and then made successively or simultaneously. This explanation would seem to indicate that it is the first response, rather than the second, which is delayed. His suggestion that "signals" may also be stored is less convincing, for it implies that the first "signal" remains, in Bartley's terms (1958, p. 99), an "impingement" until the second signal arrives, at which time both become "stimuli." Recast in this terminology the difficulties become apparent. One would have to postulate, among other things, a retroactive effect of the second "signal" on the first - an idea long ago read out of psychological theory. Storage of responses does seem possible, and would in general fit in with the claim made earlier in this paper that when two stimuli are presented in close temporal contiguity and response to both is required that a delay in response will occur to one of the stimuli.

Adams (1962) varied a time uncertainty condition associated with a 100 millisecond ISI, using an ISI range of 0 to 800 milliseconds. He found refractoriness at ISIs of less than 200 milliseconds. Errors of anticipation begin to occur at about 400 milliseconds, with little evidence of refractoriness. These results were taken to support an "expectancy" position. The task involved can be best described as a tracking task, in which the S maintained a pure tone (auditory task) and proper alignment of lights (visual task). The visual task always preceded the auditory one, so that there was event certainty; time uncertainty was introduced via statistical manipulation of frequencies of each ISI. Adams

used as his performance measure what he called "response time," which is what is earlier referred to in this paper as the RS measure (see definitions). RS differs from the "classic" RT in that the former, "...is a function of (a) off-target time between onset of the stimulus and the onset of the response, whether the response is correct or not, (b) number of errors...and, (c) duration of each error before it is corrected (p. 282)." Thus errors of anticipation are permitted, these errors being either "beneficial" or "detrimental" depending on whether or not they assist the S to make the correct response more or less quickly, respectively.

Using an experimental set-up quite similar to that of Adams (1962), Adams & Chambers (1962) held time uncertainty to zero by having all ISIs equal to 0 milliseconds. The stimulus events were either certain or not, with a bisensory and a unisensory tracking task. Findings showed that the bisensory group had a faster RS when events were certain, and this fact was thought explained by the increased speed associated with anticipation.

These studies seem to show that the net effect of time uncertainty is to cause a slowing of the second response only at the shorter ISIs (Adams, 1962), and this defines the PRP phenomenon. The effect of event uncertainty appears to be to generally depress performance, or increase latencies of response in general (Fig. 1, p. 201). Methodological difficulties are discussed below.

Creamer (1963) assigned five groups of Ss to time certain conditions, in which the ISI used was homogeneous for the group. A sixth group (time uncertain) had the same five ISIs in a random order; all groups were presented with two uncertain bisensory events in a tracking task. Using RS, just as did Adams (1962), the time uncertain group was found to have

slightly slower RS than the time certain group, but this difference was not statistically significant. Upon closer analysis the time uncertain variable was found to prolong the effects of the event uncertain variable, resulting in a delay of RS at longer ISIs for the time uncertain group. Since the time certain and uncertain conditions were not significantly different from each other on any of the comparisons, Creamer concluded that it is event, not time, uncertainty which is responsible for the PRP. Response delays were ascribed to a "...human limitation for the central decision functions of processing choices among stimuli (p. 194), "placing him squarely in the organism-centered, physiologically-oriented theoretical camp.

It may be tenable to assume that when events are uncertain (in the double stimulation paradigm) responses to both stimuli must be held in readiness to insure maximum efficiency of response. When either stimulus occurs, there may be competing response tendencies which are associated with the other stimulus which interfere with response to the first stimulus. If so, the first response may be delayed without marked delay of the second response. It is usually the case that the second response is delayed at the shorter ISIs, however. Let us consider the implications of assuming equality of response strength: if one of the two responses available to the S is not stronger than the other, then the response elicited by the first stimulus may become the prepotent response. If this is true we may expect the second response to be delayed if and only if the second stimulus occurs "too soon," after the first. At greater intervals the effects of response competition may be attenuated.

General Discussion

The area of reaction time studies in which the PRP is examined is one in which there is a welter of conflicting findings and general incompatibility across studies. The British studies typically use two to six Ss and multiple measurements. Conclusions tend to evolve from inspection of the results, rather than the testing of hypotheses. In most of these studies it is common practice to omit reports of statistical tests, if in fact they were performed. Generalization from the British to the American studies and vice versa is tenuous, for the former typically use extremely well-trained Ss and the latter typically do not, though tending to use much larger numbers of Ss. American studies tend to be both methodologically "cleaner" and more complex. Another difficulty in generalizing is that the British studies are typically reaction time studies in the classic sense of having discrete responses to discrete stimuli, with some attempt made to control or eliminate anticipatory responses. The American studies involve tracking of changing stimuli, and as such provide for many discrete responses per trial, the sum of which is the Ss "RS." In these studies errors of anticipation are permitted. If one is interested in a relatively pure measure of the response of a S to stimuli which arrive in close temporal contiguity, tracking studies are somewhat less than optimally effective.

It will be recalled that the PRP is assumed to be a special case of the more general TIR phenomenon. In order to explain the more general case a competing response position was advanced (Reynolds, 1964). Other theories, stimulus- and organism-centered, are not incompatible with a competing response theory. There are difficulties with these theories, however. A stimulus-centered explanation, while being squarely in the framework of

classic S-R theory, has difficulty in explaining what guides stimulus-selection in, e.g., stereoscopic perception and dichotic listening. If all the information to which the S must respond is carried in (or by) the stimulus, how can delays in response be handled when the stimuli are identical, differing only in temporal distribution? While these difficulties are not insuperable, they insure that an explanation exclusively in terms of the stimulus is not soon to be expected. The organism-centered explanations fare similarly. "Expectancy" as such is more nominal than explanatory.

An explanation of response delays couched in physiological terms holds more promise than the "expectancy" position and seems more amenable to testing once the neural framework has been established. Heretofore these explanations have been "central" in nature, positing a limit on the ability of humans to process information, without specifying in much detail how, much less why, this limit operates. Given the very large number of neural connections available for information processing, it would appear that the burden of proof is on those who claim a "central limitation." Broadbent (1957, 1958) has attempted such an explanation, but his discussion of Filter Theory tends to follow the data and explain specific findings. Its predictive power would seem almost too good, for it tends to "explain" differences in opposite directions equally well.

The chief advantage in dealing with the TIR phenomenon in general, and the PRP in particular, by means of a competing response theory is that operational referents for the strength of a response tendency may be provided. In an earlier paper Berlyne linked delays in reaction time to competing response tendencies (1957, p. 334). If we assume that double stimulation elicits competing responses in the S, we may expect the TIR

for a short time, after which the prepotent response should emerge (no Hullian endorsement is thereby implied, however). Further, this state of affairs may not be expected when there is a great deal of practice at the task (such that the presently hypothetical R_2 is extinguished).

By training responses to stimuli previously unassociated with them we may operationally define a prepotent response. All previous work implicitly assumes equality of response-strengths, or the absence of a prepotent response. As mentioned in the discussion of Creamer's study (1963), in this case the first-elicited response may become the prepotent response, with predictable delay to the second stimulus if it arrives "too soon." What if the first response is relatively weaker in strength than the second? Would the first response be delayed and the second facilitated? Would this result in a breakdown of the PRP? What is the second stimulus does not arrive "too soon," but at a still relatively short interval after the first? Although previous work indicates that the responses would tend to approach equality of speed (Davis, 1959), would this finding still hold up if the second response was relatively weaker in strength than the first?

An interesting finding has come from the probability learning literature. Ss in a probability learning situation typically do not use a "maximum-success strategy," but tend to follow the objective probabilities fairly closely (Restle, 1961). The probability learning task could be used to train a prepotent response and one competing response in the double stimulation paradigm. This would permit study of a competing response position within the TIR framework. If the S is placed in a probability learning situation with, e.g., a probability of .8 associated with the left-hand stimulus, it is posited that the S, in responding to the left-hand stimulus 80% of the time - which he will eventually do - will learn

kinesthetic and proprioceptive cues, with knowledge of results as reinforcement. Let us term this "left-hand response" as R_a and the stimulus to which it is made as S_a . The right-hand response and stimulus will be termed R_b and S_b , respectively.

Given the above training procedure with the probability of S_a equal to .8 and the probability of S_b equal to .2 the result will be, if the competing response position is correct, that S_a will be a potent elicitor of R_a in subsequent situations. S_b , given this situation, will be a less potent elicitor, both in relation to R_b and to R_a (with which R_b should compete). Note that this formulation does not imply that R_a will be made to S_b , but merely that the situation will set up a response competition which should have discriminable effects with respect to the TIR phenomenon, and which should vary according to whether S_a precedes or follows S_b in the double stimulation paradigm. This procedure has apparently never been used to test the underlying assumptions of a competing response position as it applies to the PRP.

Refractoriness & Uncertainty: A Methodological Critique

That the PRP is a stable phenomenon is well-known. One may nevertheless wish to ask under what conditions may it be attenuated or destroyed, or if any such conditions exist. One set of conditions has been suggested above, i.e., differential training of response probabilities. One may also suggest another set of conditions involving time and event uncertainty. The role of time and event uncertainty in refractoriness, given a unisensory two-choice task in which anticipatory responses are not permitted, is by no means clear. The studies of Adams (1962), Adams and Chambers (1962), and Creamer (1963) cannot answer this question, and the studies of Borger (1963),

Davis (1956, 1959), and Klemmer (1956) can be questioned on various grounds. These studies, although using RT as a performance measure, used few Ss who were quite variable. Further, Klemmer (1956) used ISIs longer than those used by other workers, and in a single- rather than double-choice task.

Creamer's (1963) study comes closest to investigating the role of time and event uncertainty in refractoriness, but uses a tracking task with RS, rather than RT, as a performance measure. Since in the bisensory condition the visual task always comes first (except at the 0 millisecond ISI), the RS score is confounded by the differential reaction times to visual and auditory stimuli in general. The RS measure, as noted above, is not itself an optimal measure of latency of discrete responses to discrete stimuli. When Creamer's data is examined one sees that the visual (first) response is always made with a shorter latency than the auditory response. This may be due to the instructions to make the visual response first if the S felt a delay (p. 189), and may have little to do with refractoriness as such. Since the RS includes errors and the time needed to correct them, mean latencies of RS may be a poor estimate of actual RT.

There are questions left unanswered by the studies reviewed herein. When the task involves tracking, i.e., the making of many discrete responses and adjustments until the "correct" response terminates the trial, the actual speed of response is confounded by anticipations and/or errors and a pure speed measure is lacking. In fairness to these investigators it must be said that they deliberately arranged the situation so that the Ss could anticipate and not be penalized for it. But, in encouraging anticipatory responses, it is not wholly surprising to find results supportive of an "expectancy" position. The reaction time tasks avoid this difficulty, but there are few unisensory studies, and apparently none

expressly manipulating time and event uncertainty. What would happen in unisensory tasks involving a single, discrete response to each of two stimuli? What would curves of response times (RT) to the first and second stimulus look like if errors of anticipation were excluded?

Some of these questions have been tentatively dealt with by Davis (1956, 1959). The general finding (with two Ss, obtained with time uncertainty only) is that RT to the first stimulus remains constant as ISIs are increased from 0 to 400-500 milliseconds, while the second decreases exponentially for one S and very nearly linearly for the other. The shapes of these curves are not discussed by Davis. At about 325 milliseconds ISI the response to the second stimulus becomes faster than that to the first.

The studies presented herein examined the effects of training prepotent responses by means of the probability learning task in an attempt to evaluate a competing response theory of the PRP. Further, different manipulations of time and event uncertainty were made using a unisensory two-choice task in which direct measures of RT were possible. Time and event uncertainty were thus manipulated and their effects on RT were not confounded in the manner of the RS measure.

EXPERIMENT I

Exp. I was set up to assess the effects of training prepotent responses by means of the probability learning task. The sequence of events was to give the S single-choice practice trials, then to place him in the probability learning situation and immediately afterward test him on the double-choice reaction task. All stimuli to which the S responded were visual.

Subjects

The 24 Ss were volunteers recruited from the introductory psychology course at Michigan State University. All were male, right-handed, and had at a minimum 20-20 vision, corrected. Ss were randomly assigned to experimental treatments.

Apparatus

The apparatus was a specially constructed stimulus-presentation unit. Facing the S, at a distance of approximately 86 inches from his frontal plane, was a panel 18 by 24 inches. Three holes $1\frac{1}{2}$ inches square were cut such that a horizontal line through their centers would be 12 inches above the table top on which the panel rested. The centers of the holes were 7 inches apart. The center hole was covered from the rear with a square of white frosted glass on which was affixed a small red fixation square, $\frac{1}{4}$ inch square. The two other holes were covered from the rear by the stimulus projection units of Lehigh Valley Electronics (LVE) Multi-stimulus Panels, Model #1346-462. The whole panel was painted flat black. Each visual target subtended an approximate visual angle of four degrees, and by placing the S at least 80 inches from the targets, this provides a visual fixation angle of 10 degrees. Given a stable fixation with "normal" wander, this insures that images will fall on the foveal region of the retina, giving maximum acuity.

Response keys provided for the S were Lafayette Radio Telegraph Keys, Model #MS-428. The keys were mounted on a heavy fiberglass board 1 inch thick by 6 inches deep by 24 inches wide. Keys were spaced $9\frac{1}{2}$ inches apart at their centers. The distance between contacts on each key was calibrated and maintained at .01 inch. A plywood board $\frac{1}{4}$ inch thick by

11 3/4 inches high by 11½ inches deep was placed exactly between the two keys on the fiberglass board and painted flat black.

The supporting hardware consisted of a LVE Probability Randomizer, Model #1485; a LVE Tape Programmer, Model #1319FC; a LVE Digital (Sodeco) Counter bank, Model #1425; Two LVE Bicircuit Pulse Formers, Model #1537; a LVE Power Supply (5 amp.), Model #1424; Two Standard Electric Millisecond Clocks, Model #MS-100; Three Hunter Timers, Model 100-B, Series D. All supporting hardware, with the exception of the clocks, were mounted on a desk-type relay rack. The clocks were independently mounted on a separate panel, out of sight of the S. Clocks were read visually by the E and times recorded on a specially devised form.

Procedure

All Ss were run individually. Each S was given 25 practice trials on single-choice responses with each hand, and latencies greater than 450 milliseconds were discarded. This served to establish a baseline control for each hand separately as well as to allow the S to practice making the key-pressing response. Woodworth & Schlosberg (1954) point out that Ss are near their asymptote on practiced RT with 50-100 trials; further practice adds little proficiency.

Instructions to S for this part were:

Take a comfortable position in your chair. The keys in front of you are to be used for your reaction to the stimulus lights. I will present you with a signal from one of the two darker screens, left or right, one at a time. I want you to **react** to the onset of a light by pressing down on the key as fast as you can. First we will use the left (right) light. Each time the light goes on, press down on the left (right) key with the first finger of your left (right) hand. Always use the first finger of each hand for your response. I will let you know when we switch to the other side. Any noises which you may hear from the equipment are to be ignored. Remember, you will have to be on your toes, as there will

be no warning signal. Is that clear? Finger on the left (right) key now, please.

There was a 20 second rest after each block of 10 trials.

After the single-choice practice, Ss went directly into the probability learning (PL) situation. Instructions to S were:

I want you to guess which light will go on by pressing down on the key which corresponds to your guess. If you think the left light will go on, press down on the left key. If you think the right light will go on, press down on the right key. As before, use only the first finger of each hand for your guess. As soon as you press the key, one of the two lights, left or right, will go on telling you if your guess was correct. As soon as the light goes out, this is your signal to make another guess. Try to work at a reasonable pace, that is, do not spend too much time in making your guess. Try to get as many right as you can. Is that clear? Fingers on keys now, please.

Depression of either key by the S then turned on a light according to a random schedule under the control of the probability randomizer. The bank of Sodeco counters registered for each stimulus (left or right) two events: 1) The number of times the S actually pressed that key (left or right), and 2) The number of times each light was illuminated. The background of the left hand light was always red and of the right hand light always green; each had three white dots superimposed (use of studs numbered 4 & 10 and 5 & 11, respectively, on the Multistimulus Panel achieved this result). The dots were horizontally aligned on the left hand light, and vertically on the right, yielding two discriminative cues for the S (color and alignment of dots).

This situation is analogous to the free-operant situation in that the S generates his own sequence of events by pressing the keys to signify his guesses. Each S received 600 trials in the PL task. The vertical panel between keys insured that S used different hands for each response instead of crossing over and making both responses with the same

hand. 12 Ss received 80% of the stimuli on the left, and 12 received 80% on the right.

Immediately after completion of the PL task, instructions for the double-choice task were read to the S as follows:

I want you to look at the little red square on the panel and place the first finger of each hand on the proper key. I will be showing you some lights in pairs, and I want you to respond to each. You are to respond to the left light with the left key, and the right light with the right key. You must be very careful not to jump the gun, that is, to press down on a key before the light goes on. Remember, each light has its own response. Sometimes there will be only one light, and not two. If you press the second key before the second light goes on, we will have to throw out that trial and the five just before it, so stay on your toes. There will be no warning signal before the lights go on. Sometimes the first light will be on the right and sometimes on the left. Respond only when the light goes on. Is that clear? Fingers on keys now, please.

ITIs (times between presentation of pairs of stimuli) were programmed on a VI 10 schedule, with a range of 5 to 20 seconds. This means that pairs of stimuli were randomly presented 5 to 20 seconds apart, with a mean of 10 seconds. (The actual mean ITI was 10.43 seconds.) Each stimulus was on the screen for 95 milliseconds, the same length of time as in the PL situation. There were 50 test trials for each S. The design was a 2 x 6, with 2 Ss in each cell.

As a control against anticipatory responses and to introduce event uncertainty, the stimuli were presented with the right stimulus first in half the trials in a random order; the left stimulus was first in the other half, such that the probability of a right-to-left order equalled that of a left-to-right order = .5. Each S always received the same ISI; intervals of 0, 100, 200, 300, 400, and 500 milliseconds were used with four Ss at each ISI. Two of each four Ss were those trained in the PL task with 80% of the signals on the right-hand side; the other two had

been trained with 80% of the signals on the left. Note that this design provides event uncertainty with complete temporal certainty for all Ss (except those in the 0 millisecond group, who had both complete event and temporal certainty). Latencies of response greater than 800 milliseconds for either hand were discarded, and the trial re-run. This was in an attempt to control "grouping" of responses (in which the S may wait until both stimuli have occurred, and then respond with a joint, much delayed, response to both), and to eliminate extremely atypical RTs. Previous pilot work showed that a latency of 800 milliseconds in this task were rare. After trials #13, 25, and 37, the S received a 20 second rest.

Hypotheses

It was predicted that Ss in the PL condition where 80% of the responses were made on the left-hand key would have faster RTs in the two-choice RT task with the left-hand than Ss who had 80% of their PL choices made on the right-hand key. This hypothesis grew out of a belief that S_a (the left-hand light) would become a potent elicitor of R_a (the left-hand key press) in subsequent conditions. R_a should therefore be made faster to S_a than R_b should be made to S_b . This hypothesis holds, of course, only for those Ss who made 80% of their responses in PL on the left-hand key. The reverse was hypothesized for those Ss who made 80% of their responses on the right-hand key.

Results

Mean RTs in milliseconds (msec.) for the two groups of Ss according to their PL treatment are presented below in Table 1.

Table 1

Mean RTs (in msec.) for Subjects by Probability Learning Group

80% Probability of Left-Hand		80% Probability of Right-Hand	
$\bar{X}$ Left-Hand	$\bar{X}$ Right-Hand	$\bar{X}$ Left-Hand	$\bar{X}$ Right-Hand
354.40	368.20	351.68	382.24
$\bar{X}$ 1st Response*	$\bar{X}$ 2nd Response*	$\bar{X}$ 1st Response*	$\bar{X}$ 2nd Response
369.03	352.62	382.68	351.24

*N.B. These means exclude data from the 0 msec. Ss.

As can be seen from Table 1, mean latencies for both PL groups were higher for right-hand responses than for left-hand responses, and so no further analyses were made. Averaged across five ISIs, with the 0 msec. groups excluded from the analysis, the mean first response took slightly longer than the second, but this difference is not statistically significant ($p > .05$, two-sided, sign test). This analysis confounds ISIs, and so Table 2 presents a comparison of mean RTs for groups of Ss at each ISI, regardless of the PL group from which the Ss came. The 0 msec. groups are omitted.

Table 2

Comparison of Mean RTs (in msec.) of 1st and 2nd Responses by ISIs

n	ISI in Msec.	$\bar{X}$ First Response	$\bar{X}$ Second Response
4	500	332.78	291.80
4	400	395.24	368.33
4	300	378.30	335.54
4	200	372.34	382.34
4	100	310.78	313.48

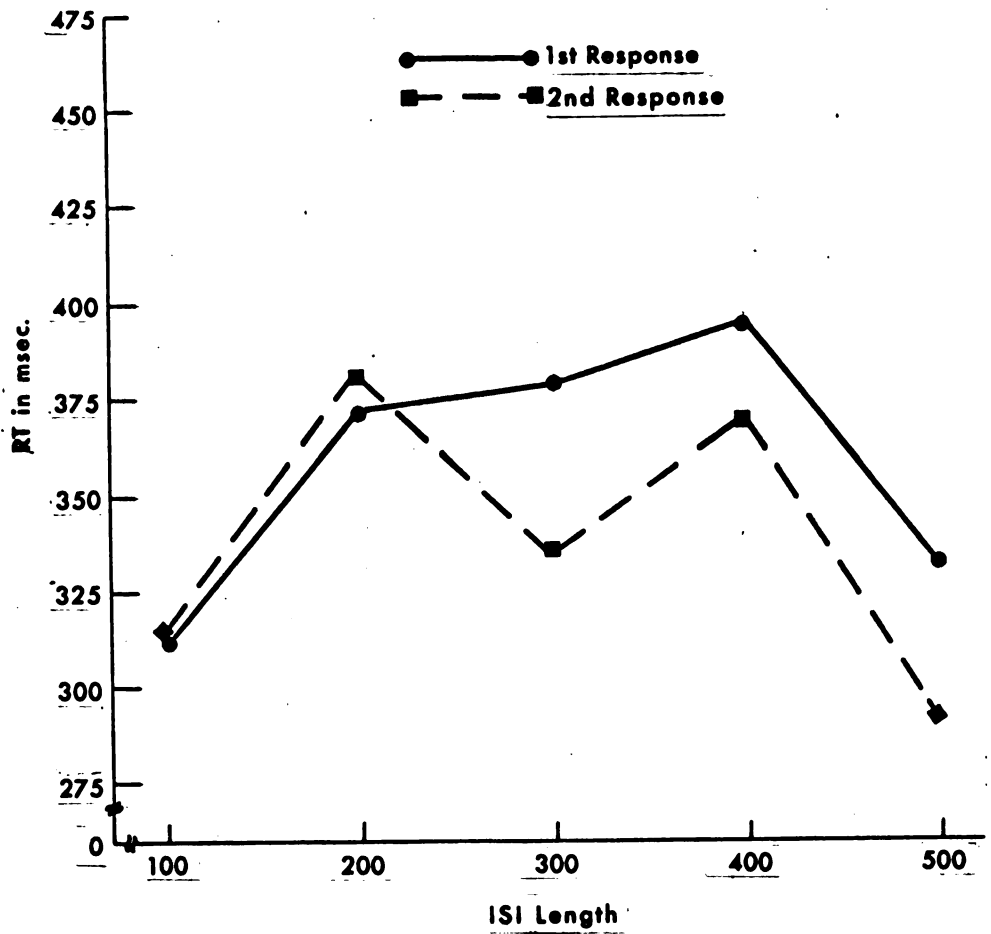


Figure 1. Reaction Time of 1st and 2nd Response as a Function of ISI Length (Experiment I).

Figure 1 presents a graph of mean RTs, and reflects the data in Table 2. (See page 22)

Table 3 summarizes a Lindquist (1953) Type III Analysis of Variance on the data of Exp. I, where Left Hand vs. Right Hand corresponds to Lindquist's "A" classification, and the Probability Levels and ISIs correspond to "B" and "C" respectively.

Table 3

Lindquist Type III Analysis of Variance of Data From Experiment I
(Left Hand vs. Right Hand)

Source of Variance	df	Mean Square	F
<u>Between Subjects</u>			
Probability Levels (PL)	1	93,060.00	<1.00
Interstimulus Inter- vals (ISI)	5	7,965,186.80	<1.00
PL x ISI	5	242,429.40	<1.00
Subjects within groups (Error)	132	94,697,898.40	
<u>Within Subjects</u>			
Left vs. Right Hand (H)	1	1,996,835.00	11.92*
PL x H	1	1,668.00	<1.00
ISI x H	5	251,670.80	1.50
PL x ISI x H	5	26,478.20	<1.00
H x Subjects within groups (Error)	132	167,424.28	

* p less than .01

As will be noted, the only significant F was that associated with the Left vs. Right Hand classification. Discussion of this finding will be deferred until after presentation of Exp. II. Table 4 summarizes an analogous Type III Analysis of Variance of the data of Exp. I, with the data recast so that the "A" classification represents First Hand vs. Second Hand, and the "B" and "C" classifications remain the same as above.

Table 4

Lindquist Type III Analysis of Variance of Data From Experiment I
(First Hand vs. Second Hand)

Source of Variance	df	Mean Square	F
<u>Between Subjects</u>			
Probability Levels (PL)	1	93,060.00	< 1.00
Interstimulus Inter- vals (ISI)	5	7,965,187.00	< 1.00
PL x ISI	5	242,429.00	< 1.00
Subjects within groups (Error)	132	94,697,898.00	
<u>Within Subjects</u>			
First vs. Second Hand (0)	1	6,717,029.00	10.80*
PL x 0	1	46,537.00	< 1.00
ISI x 0	5	717,488.00	1.10
PL x ISI x 0	5	238,875.00	< 1.00
0 x Subjects within groups (Error)	132	620,399.00	

* p less than .01

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes the need for transparency and accountability in financial reporting.

2. The second part of the document outlines the various methods and techniques used to collect and analyze data. It includes a detailed description of the experimental procedures and the statistical analysis performed.

3. The third part of the document presents the results of the study. It includes a series of tables and graphs that illustrate the findings of the research.

4. The fourth part of the document discusses the implications of the findings and provides recommendations for future research. It also includes a conclusion that summarizes the main points of the study.

The following table shows the results of the experiment for different values of the parameter α . The data is presented in a clear and concise manner, allowing for easy comparison of the results.

Table 1: Results of the experiment for different values of α		
α	Mean	Standard Deviation
0.1	1.23	0.45
0.2	1.45	0.52
0.3	1.67	0.58
0.4	1.89	0.65
0.5	2.11	0.72
0.6	2.33	0.79
0.7	2.55	0.86
0.8	2.77	0.93
0.9	2.99	1.00
1.0	3.21	1.07

The results of the experiment show that the mean value increases as the parameter α increases. This is consistent with the theoretical predictions of the model. The standard deviation also increases with α , indicating that the variability of the data increases as the parameter value increases.

The following table shows the results of the experiment for different values of the parameter β . The data is presented in a clear and concise manner, allowing for easy comparison of the results.

Table 2: Results of the experiment for different values of β		
β	Mean	Standard Deviation
0.1	1.12	0.38
0.2	1.34	0.45
0.3	1.56	0.52
0.4	1.78	0.59
0.5	2.00	0.66
0.6	2.22	0.73
0.7	2.44	0.80
0.8	2.66	0.87
0.9	2.88	0.94
1.0	3.10	1.01

The only significant F obtained in this analysis was that associated with the First vs. Second Hand classification. This finding will be discussed after presentation of Exp. II.

EXPERIMENT II

Since the results of Exp. I were largely negative several additional experimental manipulations were performed in Exp. II. These in general involved varying of stimulus-order, making the stimuli identical rather than distinctive, and giving fewer RT trials.

Subjects

The 36 Ss were a fresh sample from the same population as in Exp. I. All were male, right-handed, and had at a minimum 20-20 vision, corrected. Ss were randomly assigned to experimental treatments.

Apparatus

The same apparatus used in Exp. I was used in Exp. II.

Procedure

All Ss were run individually. The order of tasks was changed to PL, double-choice RT, Single-choice RT. This was done to see if the single-choice RT (which came first in Exp. I) adversely affected the PL when it occurred before the PL. In the PL part the same general instructions were provided the S, with the exception that he was instructed to make his guesses as soon as possible after the click of a metronome. The metronome was set at 42 beats per minute. This addition was to encourage a key-pressing response more similar to that the S would later be making in the RT tasks. (In Exp. I the observation was made that some Ss used a gentle key-press

The first part of the document discusses the importance of maintaining accurate records of all transactions and the role of the accounting department in ensuring the integrity of the financial statements. It also highlights the need for regular audits and the importance of transparency in financial reporting.

The second part of the document focuses on the implementation of internal controls to prevent fraud and ensure the accuracy of financial data. It outlines the key components of a robust internal control system, including segregation of duties, authorization procedures, and regular monitoring and evaluation.

The third part of the document addresses the challenges faced by organizations in managing their financial resources effectively. It discusses the importance of budgeting and forecasting, and the role of the accounting department in providing accurate and timely financial information to support decision-making.

The fourth part of the document explores the impact of technology on the accounting profession. It discusses the benefits of automation and the use of cloud-based accounting systems, and the need for accountants to stay updated with the latest technological advancements.

The fifth part of the document discusses the ethical responsibilities of accountants and the importance of maintaining high standards of integrity and honesty in their work. It also highlights the role of professional associations in promoting ethical behavior and providing guidance on ethical dilemmas.

The sixth part of the document discusses the importance of communication and collaboration between the accounting department and other departments within the organization. It emphasizes the need for clear communication and the exchange of information to ensure the accuracy and completeness of financial data.

The seventh part of the document discusses the role of the accounting department in supporting the organization's strategic goals and objectives. It highlights the importance of providing accurate and timely financial information to support strategic decision-making and the role of the accounting department in identifying areas for improvement and optimization.

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for the PL part and a different, harder, one for the RT part.)

In addition to the 80% right and left-hand groups as per Exp. I, a 50% group was also run; this group randomly got half of the PL stimuli on the left and half on the right. The design was thus a 3 x 6 with 2 Ss in each cell. Instructions for PL were:

I want you to guess which light will go on by pressing down on the key which corresponds to your guess. If you think the left light will go on, press down on the left key with the first finger of your left hand; if you think the right light will go on, press down on the right key with the first finger of your right hand. Always use the first finger of each hand for your guess. As soon as you press a key, one of the two lights will go on, letting you know if your guess was correct. The speed of your guesses is important. I want you to make your guess as soon as possible after you hear the beat of this metronome (Demonstration). You must not only make the fastest reaction possible, but you must try to get as many right as you can. Remember, wait for the beat of the metronome, then make your guess as fast as you can. Is that clear? Fingers on keys now, please.

As in Exp. I, the S was given 600 trials on the PL task. Immediately afterward he was read these instructions for the two-choice RT task:

I want you to look at the little red square on the panel and place the first finger of each hand on the proper key. I will be showing you some lights in pairs, and I want you to respond to each. You are to respond to the left light with the left key, and to the right light with the right key. As before, use only the first finger of each hand for making your response. You must be very careful not to press down on a key before a light goes on. There will be no warning signal before the lights go on. Each light has its own response.

Sometimes the first light may be on the left, and sometimes on the right. They may even go on together. Respond to each light only when it goes on. Remember, accuracy is very important, but you will have to respond as fast as you possibly can also. Is that clear? Fingers on keys now, please. Remember, each light has its own response. Use the left key only for the left light whenever it goes on, and the right key for the right light whenever it goes on.

The statistical frequencies of events were such that 25% of the time the lights went on in a left-to-right order, 25% of the time the lights went on in a right-to-left order, and 50% of the time simultaneously. Orders were random. Each S always received the same ISI; intervals of 0, 100, 200, 300, 400, and 500 msec. were used. ISIs were identical to Exp. I.

Note that this distribution of frequencies of stimulus-presentations differs from that of Exp. I. In Exp. II all groups except the 0 msec. group had a greater degree of event uncertainty than in Exp. I; in both experiments there was complete temporal certainty. As in Exp. I the 0 msec. group had both complete event and temporal certainty. (In the 0 msec. group all stimulus-pairs occurred simultaneously.) Responses with latencies greater than 1000 msec. were discarded and re-run.

The background color of the left-hand stimulus was changed from red to green, and both stimulus lights were made identical. Studs numbered 5 and 11 provided the stimuli from the Multistimulus Panel for both right and left hand sides. (There were three vertical dots superimposed on each stimulus light.)

After completing each 10 trials in the double-choice task the S got approximately a 30 second rest. A total of 40 trials per S were run. After this, S completed 40 single-choice RTs alternating between right and left-hand keys. Instructions to the S were:

I will present you with a light from one of the two darker screens, left or right, one at a time. As soon as a light goes on press down on the proper key. We use the left key for response to the left light, and the right key for the right light. We will alternate, first left, then right lights. As before there will be no warning signal, and you are to respond as quickly as you possibly can after the light goes on. Use the first finger of each hand for your response. Is that clear? Fingers on keys now, please. The first light will be on the left, then the next on the right, and so on.

After 20 trials the S was given a 30 second rest pause.

Hypotheses

Hypotheses were parallel to those in Exp. I. It was predicted that the hand which responds more in the PL task would be faster in the double-choice RT task. The group which responded with 80% left-hand responses in PL were predicted to have faster left-hand double-choice RTs than the 50% group, which in turn was predicted to have faster left-hand responses than the 20% group (i.e., the group which had 80% of its PL responses on the right-hand side).

Results

Table 5 is the analogue to Table 1, and presents mean latencies in msec. for Ss according to their PL treatments. The table includes the 0 msec. groups, as per Table 1.

Table 5

Mean RT (in msec.) for Subjects According to Probability Learning					
20% Left-Hand		50% Left-Hand		80% Left-Hand	
$\bar{X}$ Left	$\bar{X}$ Right	$\bar{X}$ Left	$\bar{X}$ Right	$\bar{X}$ Left	$\bar{X}$ Right
404.57	417.47	340.53	357.55	378.93	400.32

Table 6 presents a Lindquist Type III Analysis of Variance summary on the data of Exp. II, as reflected in Table 5. Table 6 is the analogue to Table 3.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text suggests that organizations should implement robust systems to track every detail, from budget allocations to expenditure reports.

2. The second section addresses the challenges faced by organizations in managing their resources effectively. It highlights the need for strategic planning and the allocation of funds based on long-term goals. The author argues that without a clear vision and a structured approach, organizations risk mismanaging their assets and failing to achieve their intended purpose.

3. The third part of the document focuses on the role of leadership in ensuring the success of an organization. It stresses that leaders must be proactive in identifying potential risks and opportunities. The text advises that effective communication is key to aligning the team and ensuring that everyone is working towards the same objectives. Leaders are encouraged to foster a culture of innovation and continuous improvement.

4. The fourth section discusses the importance of regular communication and reporting. It suggests that organizations should establish a clear hierarchy of information flow, ensuring that all stakeholders are kept informed of the latest developments. The text also mentions the need for periodic reviews and audits to ensure that the organization remains on track and compliant with relevant regulations.

5. The fifth part of the document explores the impact of external factors on an organization's performance. It notes that organizations must be adaptable and responsive to changes in the market and regulatory environment. The author suggests that building strong relationships with external partners and stakeholders can help organizations navigate these challenges more effectively.

6. The sixth section discusses the importance of financial stability and sound fiscal management. It emphasizes that organizations should maintain a healthy balance between their income and expenses, ensuring that they have sufficient funds to cover their obligations. The text also mentions the importance of having a contingency plan in place to deal with unexpected financial setbacks.

7. The seventh part of the document focuses on the role of technology in modern organizations. It suggests that leveraging digital tools and platforms can significantly enhance operational efficiency and data management. The author encourages organizations to invest in training and development to ensure that their workforce is equipped with the necessary skills to utilize these technologies effectively.

8. The eighth section discusses the importance of ethical considerations in organizational decision-making. It stresses that organizations should adhere to high standards of integrity and transparency, avoiding any practices that could be perceived as unethical or illegal. The text suggests that establishing a strong ethical framework can help organizations build trust and credibility with their stakeholders.

9. The ninth part of the document explores the importance of community engagement and social responsibility. It suggests that organizations should actively participate in social and environmental initiatives, contributing to the well-being of the community. The author argues that this not only enhances the organization's reputation but also helps in building a sustainable and resilient organization.

10. The final section of the document provides a summary of the key points discussed and offers some concluding thoughts. It reiterates the importance of maintaining accurate records, strategic planning, effective leadership, regular communication, adaptability, financial stability, technology adoption, ethical considerations, and community engagement. The author concludes by expressing optimism about the future of organizations that embrace these principles.

Table 6

Lindquist Type III Analysis of Variance of Data From Experiment II
(Left Hand vs. Right Hand)

Source of Variance	df	Mean Square	F
<u>Between Subjects</u>			
Probability Levels (PL)	2	4,047,891.50	<1.0
Interstimulus Inter- vals (ISI)	5	8,772,596.60	<1.0
PL x ISI	10	1,043,240.10	<1.0
Subjects within groups (Error)	198	79,011,362.70	
<u>Within Subjects</u>			
Left vs. Right Hand (H)	1	190,554.00	4.37*
PL x H	2	66,546.00	1.52
ISI x H	5	40,589.60	<1.00
PL x ISI x H	10	21,802.50	<1.00
H x Subjects within groups (Error)	198	43,556.94	

*p less than .05

As in Exp. I (Table 3), the only significant F was that associated with the Left vs. Right Hand classification. Discussion of this finding is presented below, in the general discussion of Exps. I & II.

Table 7 is the analogue to Table 2, and is presented below. This table excludes the 0 ms. group from analysis, since there is no "first" response with simultaneous stimuli.

Table 7

Comparison of Mean RTs (in msec.) of 1st and 2nd Responses by ISIs			
n	ISI in msec.	$\bar{X}$ First Response	$\bar{X}$ Second Response
6	500	383.12	317.72
6	400	382.02	306.78
5*	300	365.23	383.80
6	200	464.25	434.56
6	100	390.47	413.47

* N.B. Inadvertently, only 5 Ss were run at this ISI; data from a seventh S, run at 0 instead of 300 msec. ISI, was excluded from the analysis.

Table 8 presents a Lindquist Type III Analysis of Variance summary of the data reflected in Table 7, and is the analogue to Table 4 of Exp. I.

Also in Exp. I (Table 4), the only significant F was that associated with the First vs. Second Hand classification. (See general discussion, below). In view of the analyses of probability learning (Tables 3 and 6), no further separation according to PL was maintained.

Figure 2 presents a graph of mean responses and reflects the data in Table 7. (See page 32)

A sign test comparing the points for mean first and second response was performed at the 100 msec. ISI; these points were not significantly different ($p > .05$, two-sided). This indicates absence of the PRP at 100 msec. ISI.

Table 8

Lindquist Type III Analysis of Variance of Data From Experiment II
(First Hand vs. Second Hand)

Source of Variance	df	Mean Square	F
<u>Between Subjects</u>			
Probability Levels (PL)	2	985,897.50	<1.00
Interstimulus Inter- vals (ISI)	5	2,513,319.80	<1.00
PL x ISI	10	315,245.40	<1.00
Subjects within groups (Error)	198	18,739,821.74	
<u>Within Subjects</u>			
First vs. Second Hand (O)	1	3,030,745.00	15.26*
PL x O	2	47,636.50	<1.00
ISI x O	5	415,353.60	2.09
PL x ISI x O	10	93,349.80	<1.00
O x Subjects within groups (Error)	198	198,492.39	

* p less than .01

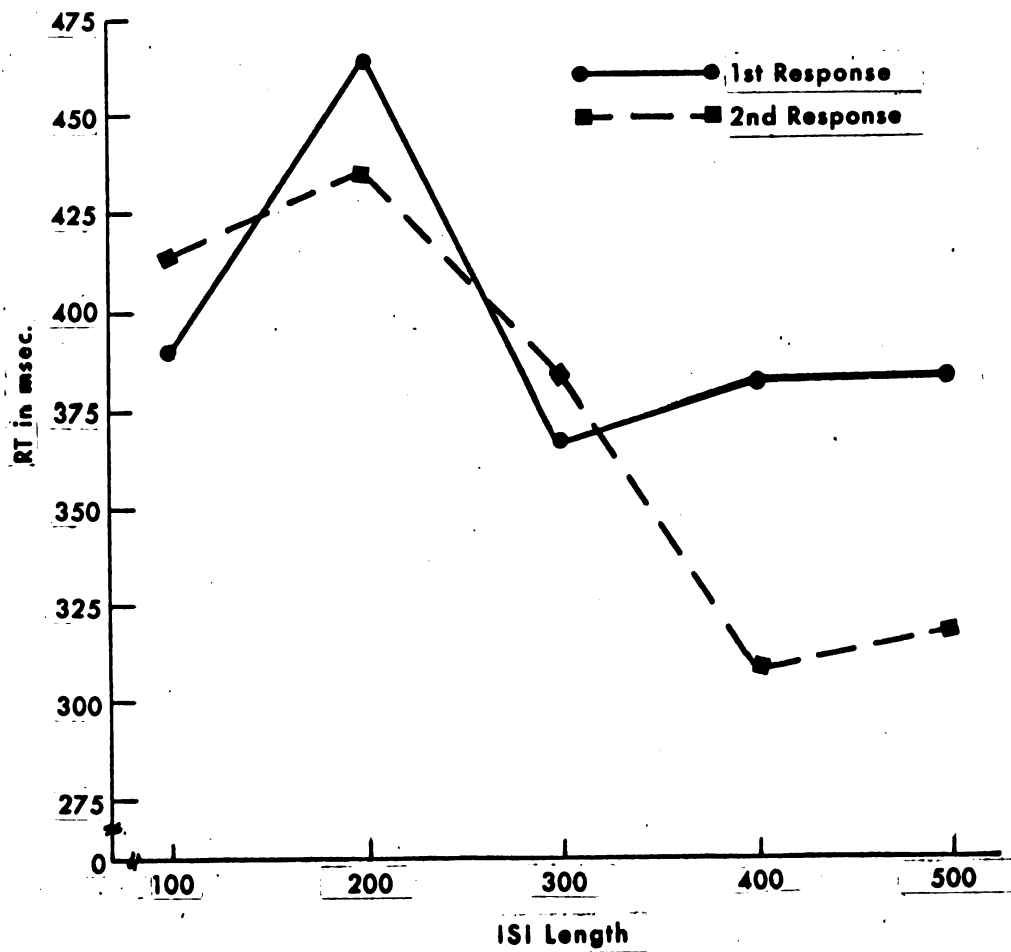


Figure 2. Reaction Time of 1st and 2nd Response as a Function of ISI Length (Experiment II).

Comparisons of Data: Exp. I vs. II

A set of comparisons were made between the data presented in Table 2 and Table 7. An overall Mann-Whitney U-test on the mean first response between the two experiments was not significant ($U = 6$; $p > .05$, two-sided). A similar test for the mean second response was also not significant ($U = 7$; $p > .05$, two-sided). A Mann-Whitney U-test comparing the individual Ss at the 100 msec. ISI for the mean second response between experiments was also made; this particular test compared the points of largest differences between Ss in both studies. The obtained U of 5 was non-significant ($p > .05$, two-sided). These comparisons show in general that the data obtained in Exp. I & II are roughly comparable in terms of mean first and second responses across ISIs.

General Discussion, Exp. I & II

The results of Exp. I & II, in which a PL task was used to attempt to train a prepotent response, were uniformly negative with respect to effects of the PL training upon subsequent two-choice RT.* This may be due to the dissimilarity of the double-choice RT task and the PL task. In the latter, the S presses a key prior to the onset of the stimulus, and with a single, rather than double, response. In the RT task the response is made after the stimulus occurs, and two responses are made in quick succession. If competing responses trained via PL are present the dissimilarity between the two tasks may override them. Furthermore, training via the PL method may be a fragile phenomenon; to overcome whatever existing habit-strengths the Ss bring into the experimental situation may require much more than the few minutes the PL task takes. Finally, the effects of complete time.

* The research hypothesis dealing with the effects of PL on two-choice RT is tested by the PL x H interaction terms in Tables 3 and 6. Neither are significant.

certainty in these two experiments may also provide for the attenuation of any response strengths presumed trained in the PL situation. One must conclude that whatever merit the PL task holds for the training of response strengths has yet to be demonstrated.

The Lindquist Type III Analyses of Variance (Tables 3 and 6, 4 and 8) show generally similar findings with respect to Exp. I and II, and so will be discussed in common. The finding of a significant within subjects effect of handedness (H) in both Tables 3 and 6 seems artifactual. The reason is simply that all subjects were right-handed, and it makes no psychological sense to expect that conditions of the experiment per se caused the left hand to respond with a shorter latency than the right (as subsequent investigation revealed). A more likely explanation is a constant error in the calibration of the equipment, probably in the tension on the spring of the telegraph key, which led to this effect. It is important to note that a constant error of this type would not affect the interaction term of PL x H, but merely reduce the latency contribution of the left hand to the interaction term.

Analogously, the finding of a significant within subjects effect of order of hand responding (O), i.e., first vs. second hand as revealed in Tables 4 and 8 may be considered. In this case, any equipment (or constant) error is evenly distributed across trials (and the hand responding) and the classification (O) is not thereby affected. Figures 1 and 2 show that the mean second response was made with a much shorter latency than the mean first response, predominantly at the longer ISIs. The interaction of ISI x O is not significant in either study. The conclusion seems tenable that there is no pronounced refractoriness at the short ISIs, while at the longer ISIs the occurrence of the first stimuli serves to act as a warning

signal for the second.

The finding of no overall difference between the two sets of curves of Exp. I as compared to Exp. II was unexpected. Since Exp. II had a somewhat greater degree of event uncertainty, one would expect greater RTs at each ISI compared to Exp. I. That this was not the case poses a theoretical problem. Creamer (1963) suggested that the PRP was caused mainly by event uncertainty. If this is the case we should expect a greater difference between the two sets of the curves at or near the point of simultaneous stimulation, and the second response should show this effect. Although this trend occurred, comparison of these points showed that the difference was not statistically significant (sign test between mean first and second response across Ss at 100 msec. ISI; $p > .05$, one-sided for each Exp.). Furthermore, an almost equally great difference was obtained at a 200 msec. ISI for the mean first response. There seems too little evidence from the first two experiments to give unqualified support to Creamer's position. The discrepancy may be resolved by looking at each experiment separately.

In Exp. I, the shapes of the curves for mean first and second response are curvilinear and not very widely separated. Note that a cross over of the two curves occurs, with the second response having a shorter latency at the longer ISIs. In Exp. II the shape of each curve is irregular, but the same effect in general holds: at the longer ISIs the second response has a shorter latency. It will also be noted that the mean first and second response made in Exp. I was shorter than the mean first and second response in Exp. II by 39.13 and 32.97 msec., respectively. Since the two sets of curves (Exp. I vs. II) are not significantly different, these differences cannot be, but they are in the "right" direction.

Note that the points of mean first and second response at 100 msec. ISI were not significantly different from each other in Exp. I or II. One may tentatively conclude that the effects of event uncertainty on refractoriness can be attenuated or destroyed by having complete temporal certainty. Any refractoriness in these conditions seems at an absolute minimum, and poses a problem for those who claim that the PRP is due to a "central limitation" of the nervous system to process information or stimulation. This finding also poses a problem for the expectancy theorists, for they would expect greater delays under the conditions of Exp. II as compared to Exp. I. These delays would be posited to occur in the second response at the short ISIs, for any "expectancy" which the S could build up is at a much lower level in Exp. II than in Exp. I. Statistical and visual inspection of the two sets of curves shows that this was not the case.

EXPERIMENT III

Exp. III explored the temporal uncertainty variable while holding events certain. Since the PL task had not provided evidence for the training of response-strengths, no further work with it was undertaken. The general manipulation within Exp. III was the presentation of "Random" or "Regular" series of ISIs, while specifying on which side the first stimulus would occur.

Subjects

The 28 Ss were a fresh sample from the same population as in the first two experiments. All were male, right-handed, and had at a minimum 20-20 vision, corrected. Ss were randomly assigned to treatments.

Apparatus

The same apparatus as in Exp. I & II was used. The probability randomizer was disconnected from the circuit.

Procedure

All Ss were run individually. The order of tasks was single-choice RT, then double-choice RT. Each S received 40 trials on the single-choice task (20 for each hand, alternately, with an approximate 30 second rest after the 20th trial), and then went into the double-choice task. Single choice RTs with latencies greater than 450 msec. were discarded.

There were two types of stimulus-presentation in the two-choice task: 1) "Random" presentation of ISIs, in which ISIs were randomly presented to the S with the restrictions that no ISI could follow itself, and that adjacent ISIs had to be at least 200 msec. apart, and 2) "Regular" presentation, in which a block of four identical ISIs (either 0 or 400 msec. in length) were presented to the S. There followed a block of four more homogeneous ISIs, either 100 or 300 msec. in length, respectively. This was continued until the last block of four homogeneous ISIs were either 400 or 0 msec. in length, respectively. The series of trials starting at 0 and ending at 400 msec. is termed an "ascending" sequence, while the series beginning at 400 and ending at 0 msec. is termed a "descending" sequence. At no time was the S informed that the interval was to be changed in the Regular series. All Ss proceeded through both the Regular and Random series; latencies greater than 800 msec. were discarded and the trial re-run.

Half the Ss ($N = 14$) got the Random series first, followed by the Regular series, and half the reverse. There were a total of 40 trials in each series; a 20 second rest separated each block of 10 trials. There was

approximately a 30 second pause between the Random and Regular series. Half of the Ss ($N = 14$) received the ascending series first; half the descending series first. Half the Ss ($N = 14$) received the first order of stimulus-presentation left-to-right, and half the reverse. The same order (left-to-right or the reverse) was kept for the first 20 trials in the Regular and Random series; after the 20th trial the S was told that the order would be reversed.

Instructions for the single-choice task were identical to those in Exp. II.

When the order of series for the S was Regular, then Random, the following instructions were given:

I want you to look at the little red square on the panel and place the first finger of each hand on the proper key. I will be showing you some lights in pairs, and you are to respond to each. Use the left key to respond to the left light whenever it goes on, and the right key to respond to the right light whenever it goes on. As before, use only the first finger of each hand for your response. Each light has its own response, and you are to respond to each light only when it goes on. The time between lights will be very short, so be sure to catch both lights and make both responses. As before there will be no warning signal, and you will have to be on your toes. The first light will be on the left (right) followed by one on the right (left) very shortly after. Respond to each light only when it goes on, and as quickly as possible. Is that clear?

After completion of the Regular series, the E said:

Now we'll continue the same way, only this time instead of a regular time between lights there will be different times between lights in a random, mixed-up order. Sometimes the lights will come on together, sometimes with a relatively long or short interval between them. Respond to each light only when it goes on. The first light will be on the left (right) followed by one on the right (left) very shortly after. Is that clear?

When the order of series for the S was Random, then Regular, the E read the instructions for the Regular series (first paragraph above) and then

continued reading the second paragraph starting with the words, "...there will be different times between lights...." After completion of the Random series, the E merely said, "Now let's continue with the first light on the left (right)."

Note that the Random group was advised that ISIs would be different on successive trials. This was an attempt to eliminate some of the "uncertainty" which the expectancy theorists maintain accrues in situations in which the S does not expect a short ISI and so is "less than optimally prepared to respond."

As a further safeguard against objections which expectancy theorists might raise, the statistical distribution of frequencies of ISIs was the same for all Ss across the Regular and Random series. Each series contained eight ISIs of 0, 100, 200, 300, and 400 msec.; four were in the order left-to-right, and four in the reverse order. Within the Random series each block of ten trials had two of each ISI. ITIs were identical to those used in Exp. I.

Since Ss always knew on which side the first stimulus would occur, this experiment compares two-choice RTs in two conditions of temporal uncertainty while holding event uncertainty to zero. The direct comparison, on the same Ss (a "within Ss" comparison), between the Random and the Regular series permits an assessment of the effect of increasing temporal uncertainty while holding event uncertainty to zero.

Hypotheses

Based on the conclusions tentatively arrived at in the discussion of the work of Adams (1962) and Adams & Chambers (1962), as well as in the discussion of Exp. I & II, it was hypothesized that there would be a delay

of response to the second stimulus at "short" ISIs, i.e., the PRP would be obtained under the conditions of Exp. III. The basis for this was that event uncertainty per se is thought to result in longer latencies across ISIs, and not necessarily in the PRP. (Creamer, 1963, would not agree.) This is because each response, when separately held in readiness, may compete with the other and result in generally longer latencies. When events are certain, the only "problem" with which the S must deal, is when to get the second response out with minimal delay. (This of course assumes a motivated S.) At longer ISIs the first stimulus can possibly serve as a warning signal for the second, this is less true at shorter ISIs, for the first response may already be underway when the second stimulus arrives. If the competing response theory of delays in response is correct, one would look for maximum delays in response to any stimulus if that stimulus arrives while another response is ongoing. This is intended as a generalization; specific exceptions may be found. The generalization was first developed in the discussion of a paper by Helson & Steger (1962) by Reynolds (1964) as follows:

Helson & Steger (1962) presented two "stimuli" to the S, only the first of which required response, at ISIs of 0 to 180 msec. The "first" (only) response was found to be delayed when the ISI was 10 to 170 msec., with maximum effect in the range 40-140 msec. If S is not required to respond to both stimuli, how could his only response be delayed by a presumably irrelevant signal? Here one sees the inadequacy of a stimulus-centered or organism-centered explanation; instead one might wish to consider what a theory of response competition has to contribute.

Let us assume a mean reaction time close to 200 msec. for each S, and let us further assume that a response develops or "unfolds" over time. One may then conceptualize a graph of response-segments plotted against unit time (on the abscissa). If we assume the simplest (but not necessarily correct) function, that of a straight line, then each increment of 20 msec. results in roughly 10% of the response moving toward completion. If the maximum effect of the application of a second signal is in the range 40-140 msec., then we can see that the response is somewhere between 20% and 70% complete when the second (irrelevant) signal is applied. It seems likely that a positively accelerated curve more accurately depicts response-segments as a function of unit time. If so, the above discussion must be modified. The curve of response-segments over time will be displaced to the right of the straight-line function, indicating that relatively more time must pass before a response is, say, 50% complete. Thus the effect of the formation of competing responses may be magnified, and the more rapid the acceleration of the curve, the greater the effect. The empirical questions remaining unanswered are these: 1) Will competing responses form to a signal which is not to be responded to? 2) Does enough time elapse during the elaboration of a response (such as made in RT) for a competing response to form?

The effects of increasing temporal uncertainty were hypothesized to be greater in the Random than the Regular series; a greater delay in the second response ~~was~~ thus expected in the Random series.

Results

Table 9 is an analogue to Table 7, and presents mean RTs in msec. for the first and second response of all 28 Ss in both the Regular and

Random series.

Table 9

Mean First & Second RTs (in msec.) in Regular & Random ISI Presentations

ISI	Regular		Random	
	$\bar{X}$ First	$\bar{X}$ Second	$\bar{X}$ First	$\bar{X}$ Second
400	273.86	242.47	300.67	273.20
300	269.86	252.41	292.67	277.05
200	266.89	270.93	280.33	295.02
100	262.91	272.63	273.58	342.17
0	258.13	343.47	267.33	443.86

Note that the Random series has a longer latency at every ISI for both the mean first and second response. A Wilcoxon matched-pairs, signed-ranks test shows this discrepancy to be significant ($p < .01$, two-sided). Latencies in the Random series are thus seen to be longer than those in the Regular series, and this is in accord with the prediction based on the greater temporal uncertainty in the Random series.

It will also be noted that the ordering of mean responses is the same for both the Random and Regular series. As the ISI decreases from 400 to 0 msec., the latency of the first response decreases, while the latency of the second response increases. For both series the second response becomes faster than the first at between 200 and 300 msec.

A Friedman two-way analysis of variance by ranks was performed on each set of data on which the four columns of Table 9 are based. Only the ranks of the first column (Regular series, mean first response) was statistically non-significant ($p > .05$, two-sided). Each of the remaining

three sets of ranks was highly significant ($p < .001$, two-sided). The interpretation of this finding is that when mean RT latencies are converted to ranks one cannot maintain that there is no difference in latencies across ISIs. Stated in another way, it appears that two-choice RT (given conditions of Exp. III) is systematically affected by increasing or decreasing ISIs. In order to graphically demonstrate this, the results of Table 9 were plotted; this is presented as Figures 3 and 4. Figure 3 presents the Regular series; Figure 4 presents the Random series. (See pages 44 and 45)

Note that in both Figures 3 and 4 the curve for the mean first response rises slowly and linearly from 0 to 400 msec. (statistically significant in both by means of a sign test, $p < .03$ and $p < .004$, two-sided, respectively). The drop in mean second response from 0 to 400 msec. ISI is also significant by means of a sign test on each curve at well beyond $p < .0001$, two-sided.

Sign tests were performed on points between mean first and second response on each of the figures at 200 and at 100 msec. The difference between mean first and second response at 200 msec. on each figure is not significant ($p > .05$, two-sided), but the same comparison at 100 msec. is significant ($p < .008$, two-sided on Figure 3; $p < .0001$, two-sided on Figure 4). Since the 0 msec. ISI points for mean first and second response on each figure are more widely separated, they are at least as significantly different as the 100 msec. points. Thus the PRP is found in Exp. III at an ISI of at (or less than) 100 msec. This is in accord with the prediction that the PRP will occur at the "short" ISIs.

In an attempt to determine if the ascending or descending series within the Regular series were differentially affecting the overall shapes

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters.

2. The second part outlines the various methods and tools used to collect and analyze data. This includes the use of surveys, interviews, and statistical software to ensure that the information gathered is reliable and valid.

3. The third part focuses on the ethical considerations surrounding data collection and analysis. It stresses the need to protect individual privacy and to use the data responsibly, avoiding any potential for misuse.

4. The fourth part describes the process of interpreting the results of the data analysis. It highlights the importance of context and the need to consider multiple perspectives when drawing conclusions.

5. The fifth part discusses the challenges and limitations of the research process. It acknowledges that while data analysis can provide valuable insights, it is not without its own set of difficulties and constraints.

6. The sixth part provides a summary of the key findings and conclusions of the study. It reiterates the importance of the research and the potential for future work in this area.

7. The final part of the document includes a list of references and a bibliography, providing credit to the sources of information used throughout the study.

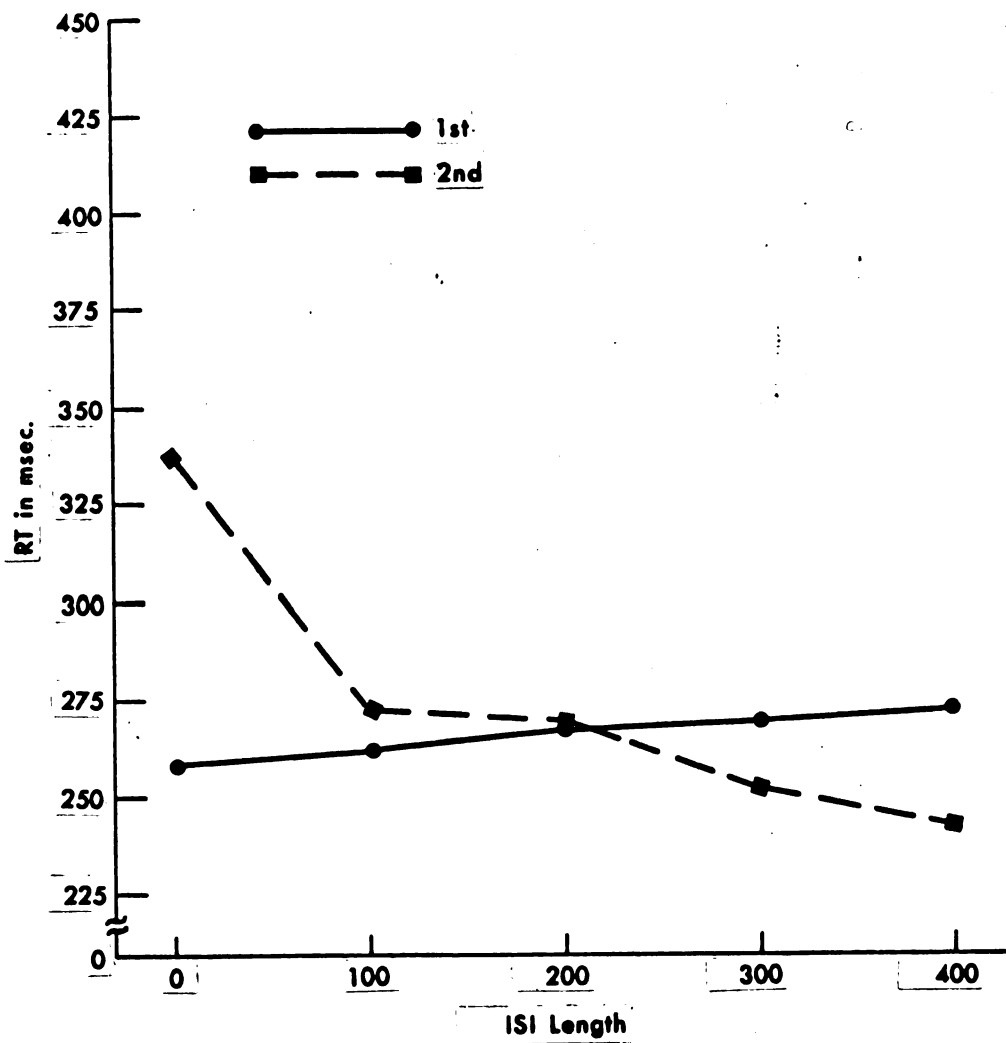


Figure 3. Reaction Time of 1st and 2nd Response as a Function of ISI Length (Experiment III-Regular).

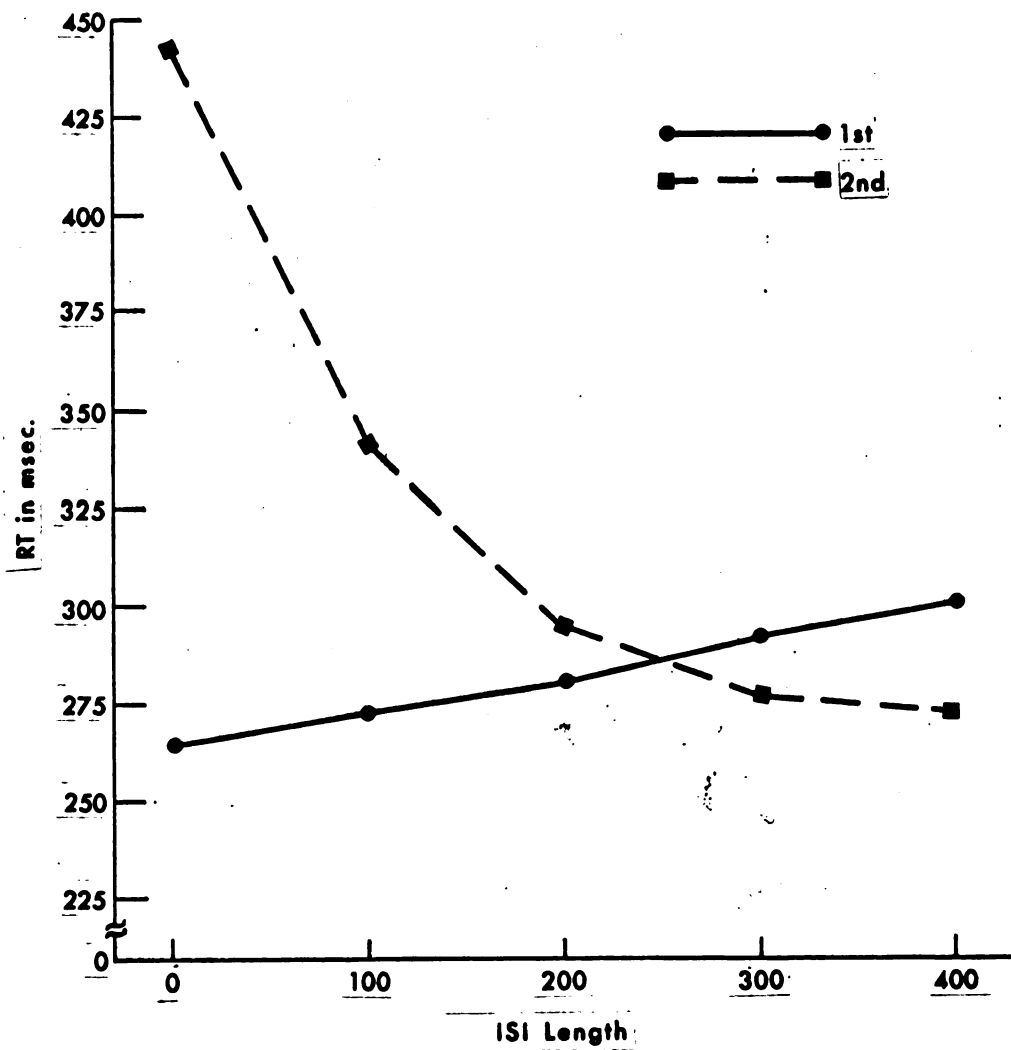


Figure 4. Reaction Time of 1st and 2nd Response as a Function of ISI Length (Experiment III-Random).

of the Figure 3 curves, a Wilcoxon matched-pairs, signed-ranks test on the mean latencies of first and second response at each ISI was computed between the ascending and descending series. The difference between the ascending and descending series was not significant ($p > .05$, two-sided), justifying the combination of the two sequences into one Regular series for the analysis.

Discussion

The results of Exp. III demonstrate that the PRP can be obtained under conditions of temporal uncertainty, even with complete event certainty. This is in sharp variance with Creamer's (1963) discussion, although it is in accord with Klemmer's (1956) findings. Since neither of these two studies used a discrete, two-choice RT task, generalization across studies is tenuous at best. It will be recalled that Adams (1962) found refractoriness at "short" ISIs using a tracking task under conditions analogous to those of Exp. III. RS was the speed measure, however. Taken together with the findings of Adams & Chambers (1962) discussed above, the conclusion that the effect of event uncertainty is to elevate latencies of both responses, while the effect of temporal uncertainty is to elevate latencies of the second response only at "short" ISIs, seems supported by the results of Exp. III.

Even though the results of Exp. III are in general accord with those of Adams (1962) and Adams & Chambers (1962), they are not necessarily best explained by the "expectancy" position. Since Exp. III did not permit anticipatory responses, one may reasonably minimize the role of "expectancy" in accounting for the data. The response competition outlined in the Hypotheses section of Exp. III offers an at least equally plausible account.

The difference in the Random and Regular sets of curves was obtained from the same Ss in a "within Ss" design. (Each point on each curve reflects mean data of all Ss.) The effect of manipulating ISI randomness (increasing temporal uncertainty) seems to lead to a greater change in the shape of the mean second response curve than the first. The curve for mean first response rises somewhat more steeply as ISI length increases in the Random series compared to the Regular series. The curve for mean second response changes from a near-linear or perhaps slightly exponential decreasing function to a sharply delineated exponential decreasing function. It is tempting to speculate that the effects of increasing temporal uncertainty results in some logarithmic increase of RT to the second stimulus presented, whereas the effect on RT to the first stimulus presented would appear linear and additive.

EXPERIMENT IV

Borger (1963; discussed on pp. 6 & 7) could not support a theory of refractoriness based on temporal uncertainty from his data. He combined temporal certainty with event uncertainty in a bisensory RT task. He found the PRP at ISIs of 300 msec. or less. Exp. IV explored the possibility of extending and generalizing his findings, and to further investigate possible experimental manipulations affecting the shapes of the curves for the mean first and second response.

Exp. IV has three parts: Part A is a "between Ss" design in which each S received one and only one ISI. Part B is a "within Ss" design in which each S received different ISIs in blocks of 10 homogeneous ISIs. Part C is a replication of Part B, with somewhat different instructions to

the S. In each part the S always knew to which side the first response would have to be made, hence there was complete event certainty. There was complete temporal certainty as well; Exp. IV thus explores the role of both event and temporal certainty in a "between Ss" and in a "within Ss" design, using the two-choice RT task.

Subjects

Ss (N = 36) were a fresh sample from the same population as in Exp. I. All were male, right-handed, and had at a minimum 20-20 vision, corrected. There were 12 different Ss in each part, assigned randomly to experimental treatments A and B, and run consecutively in Part C. Within Part C, Ss were randomly assigned to ISI sequences.

Apparatus

The apparatus used was identical to that used in Exp. III.

Procedure

All Ss were run individually. The procedure for Part A was as follows: Ss received 20 single-choice practice RT trials (10 with each hand alternating; latencies greater than 275 msec. were discarded, and the S told he was "too slow"). The following instructions were then read:

Now I will present you with some lights in pairs, and you are to respond to each, using the left key for the left light and the right key for the right light. The time between lights will be very short, and as before there will be no warning signal, so you will have to be on your toes. The time between the two lights will always be the same, and you must respond as quickly as you possibly can to each of them. (The first light will be on the left (right) followed by one on the right (left) shortly thereafter.) I am now going to show you a pair of lights to acquaint you with the interval between them, but do not respond to this first pair (Demonstration). All right, fingers on keys now,

please. (The first light will be on the left (right) just as I have shown you.) Respond to each light only when it goes on. Try not to "jump the gun." Is that clear?

The sentences in parentheses were omitted for the Ss whose only ISI was 0 msec.

Ss were then given 50 two-choice RT trials in the specified order at one of six ISIs; 0, 50, 100, 200, 300, and 400 msec. ISIs were used in all three parts of Exp. IV. There was a 15 second break between blocks of 10 trials. After the 50th trial, Ss received a two to three minute break, and then were informed that the experiment would continue, but with the order of stimuli reversed. One trial to which the S did not respond was again given him to acquaint him with the new stimulus-order. The S was then given 50 more trials in blocks of 10 at the same ISI, just as above. Only one randomly assigned ISI was used per S; there were two Ss at each ISI.

Part B differed from Part A in that each S after completing the 20 practice trials, was read the same instructions as for Part A, and was then given a block of 10 trials in which the ISIs were identical. The S then received a 15 second rest, and was then informed that the E was going to change the interval while keeping the previously specified order the same. One trial to which the S did not respond was given to acquaint him with the new interval. This was repeated after each block of 10 homogeneous trials, each with a different ISI. ISIs were selected randomly for the sequence with the restriction that each had to appear equally often as the first, second, third, fourth, fifth, and sixth in order. After 60 trials, exhausting the possible ISI orders for a specified sequence (either right-to-left or the reverse), the S was given a two to three minute break.

He was then told that the experiment would continue with the reverse stimulus order, and was given one demonstration trial to acquaint him with both the new interval and order. Latencies greater than 800 msec. were discarded, and the trial re-run.

Part C, in an attempt to explain the rise in the mean first response latency as the ISI increases from 0 to 400 msec., was run after Parts A & B had been completed; Part C duplicated the procedures of Part B, but tried via instructions to eliminate the rise in mean latency of the first response. Instructions to the S were identical to those for Part B, and the following was added at the end of the instructions:

When you respond to each light be sure that you are as quick in your response to the first as to the second light, that is, each light is to be responded to equally quickly, and each accounts for 50% of your "speed score." It's just like a two-item test with each item weighted equally. Is that clear?

In addition, before each new block of 10 trials, the S was reminded as follows:

Remember that each response has equal weight in your speed score. Respond to each light only when it goes on, and be equally fast with each hand.

ITIs throughout Exp. IV were identical to those in Exp. I.

Hypotheses

For the data of Part A it was postulated that no delay of response to either stimulus would be found. With completely predictable events (foreknowledge of which response to make first) and completely predictable ISIs (foreknowledge of when to make the second response), there may be in fact only one stimulus to which the S responds - the first. If this is true then there is but one response, a composite of two motor reactions, and no competing responses may be formed.

Part B may be meaningfully compared with the Regular series of Exp. III, for the only differences are slight: 1) The former uses 10, rather than four, trials at each ISI, and 2) In the former (Part B, Exp. IV) the S is told when the ISI is changed, but not in the latter experiment. Part B thus has more event certainty than the Regular series of Exp. III. Accordingly, it was expected that any refractoriness obtained would be less in magnitude than obtained in Exp. III, Regular series.

Instructions in Part C were aimed at flattening out the curve for the mean first response, and possibly also affecting the mean second response as well. In Exp. III it was noted that the curve for the mean first response rises as the ISI increases from 0 to 500 msec. By instructing the S to be equally fast with each hand, it was posited that the curve for the first response would flatten. It was hypothesized that the points on the mean first response curve for 0 to 400 msec. would not be different.

Results

Table 10 is an analogue to Table 7 and 9, and presents mean first and second responses at each ISI for Parts A, B, and C.

A sign test performed on the data of Part A for all ISIs except the 0 msec. one compared the mean first with the mean second response for each block of 10 trials per S. The difference between responses was highly significant ($p < .0001$, two-sided), indicating that the mean

Table 10

Mean First and Second RTs (in msec.) in Complete Temporal & Event
Certainty

ISI	Part A		Part B		Part C	
	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_1$	$\bar{X}_2$
400	250.16	172.22	286.61	224.10	270.90	228.52
300	268.49	180.55	277.84	223.19	277.77	231.59
200	241.20	192.94	267.99	250.49	260.42	243.16
100	200.92	178.42	254.80	261.14	254.90	260.78
50	220.29	186.60	254.54	270.54	251.51	280.18
0	190.51*	190.51*	245.64	289.22	241.80	272.04

*N.B. No "first" response. Figures represent extrapolations from means of each hand, and are presented for comparison only.

second response was made with a shorter latency than the first in the vast majority of blocks of 10 trials each.

A Friedman two-way analysis of variance by ranks was computed for the mean first and second response in Part B. Both the ranks of mean first and mean second responses were significantly different across ISIs ($p < .001$ and $p < .01$, respectively, two-sided). The interpretation possible from this test is that when mean RT is converted to ranks there appears to be differences across ISIs. When one looks at the magnitude and direction of the differences across ISIs, one finds that the mean first and second RTs are inversely ordered by ranks.

A Friedman two-way analysis of variance by ranks was computed in an analogous fashion for Part C. The ranks of mean first and second RTs are also significant across ISIs (both at $p < .001$, two-sided). The results of Parts B and C indicate that as the ISI lengthens the mean first response tends to increase in latency while the mean second response tends to decrease in latency.

When Part A is compared with Part B by means of a Mann-Whitney U-test on mean responses at each ISI (excluding the 0 msec. ISI), Part A is significantly different from Part B with respect to both the mean first and second response ($U = 3$, $p = .028$, one-sided and $U = 0$, $p < .004$, one-sided, respectively). When Part A is similarly compared with Part C, the identical result occurs, with the same levels of significance. A comparison of Parts B and C on the mean first response by means of a Mann-Whitney U-test was not significant ($U = 16$; $p > .05$, two-sided). A

Mann-Whitney U-test between mean second responses between Parts B & C was also not significant ($U = 17$; $p > .05$, two-sided). These tests indicate the comparability of Parts B and C, and show that the results of Part A is quite different from Parts B & C. Figure 5 presents a graph of the data in Table 10, Part A. (See p. 54)

The mean first response curve rises irregularly but sharply as the ISI lengthens. A sign test comparing the 50 and 500 msec. point is somewhat on the conservative side, since the lowest and highest points are at 100 and 300 msec., respectively. Nevertheless, the sign test was highly significant ($p < .001$, two-sided), indicating that the rise in the curve cannot be due to "chance" factors. The generally flat appearance of the curve for the mean second response was tested by means of a sign test for the points at 200 and 400 msec. ISI, and this difference was found to be highly significant ($p < .006$, two-sided). As the ISIs increase beyond 200 msec. there seems to be some room for decrease in latency of the second response. These results partly confirm the first hypothesis. Although there is no evidence of refractoriness in the second response, the mean first response does increase in latency as ISI length increases. In order to confirm the first hypothesis, both curves should be flat, with the mean second below the mean first response curve.

Figure 6 presents a graph of the data in Table 10, Parts B & C. (See p. 55) In Figure 6 the curve for the mean first response is again seen to rise sharply, and again the rise is significant by means of a sign test ($p < .006$, two-sided). Similarly the drop in the mean second response

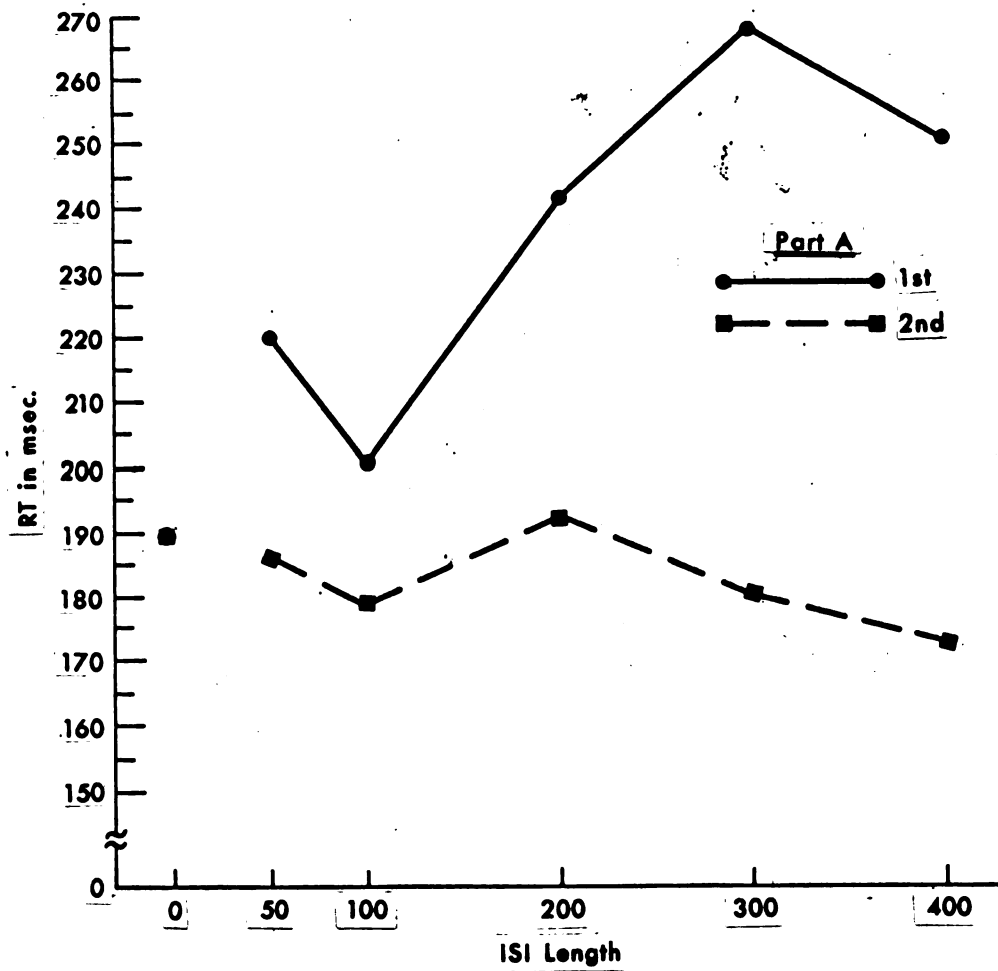


Figure 5. Reaction Time of 1st and 2nd Response as a Function of ISI Length (Experiment IV-Part A).

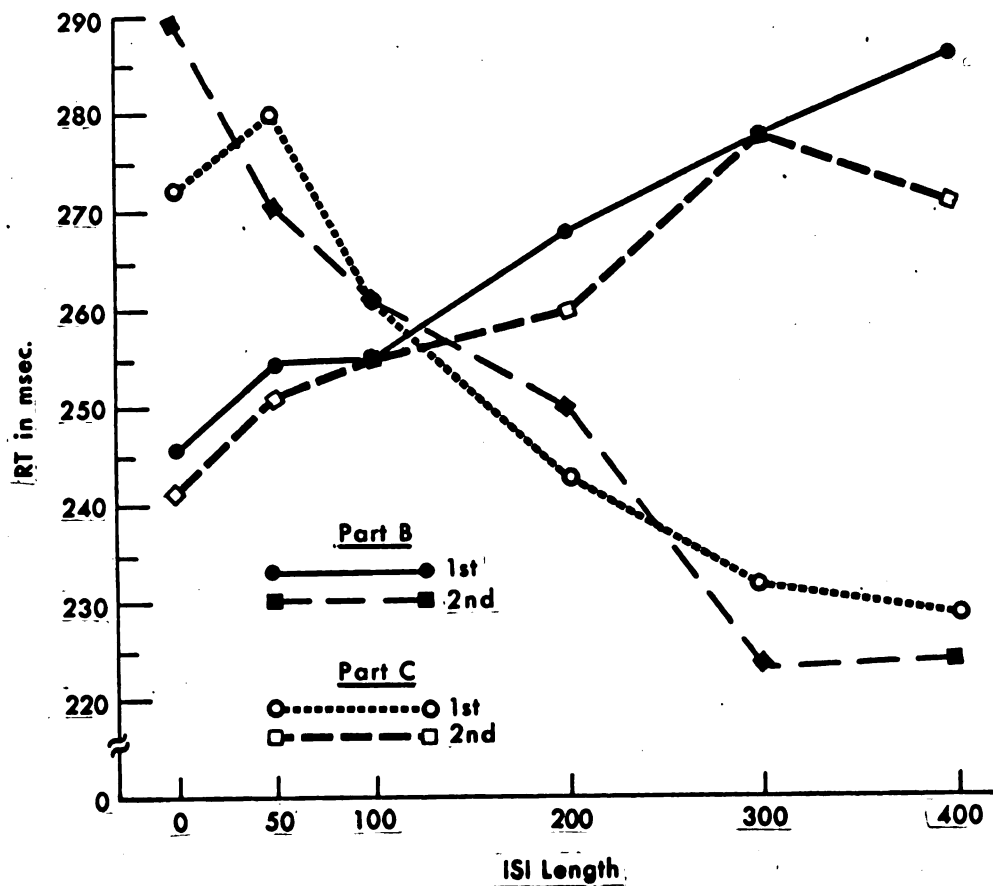


Figure 6. Reaction Time of 1st and 2nd Response as a Function of ISI Length. (Experiment IV-Parts B & C).

latency as the ISI lengthens is also significant ($p < .006$, two-sided). A sign test between mean first and second response at the 50 msec. ISI is not significant ($p > .05$, two-sided), nor is a Wilcoxon signed-ranks test. (Siegel, 1956, p. 78 suggests that a sign test is not very powerful as a test of this type, and so the Wilcoxon was run as a double-check). A sign test at the 0 msec. point is highly significant, however ($p < .006$, two-sided). Thus refractoriness, in conditions of complete event and temporal certainty, is found only at the 0 msec. ISI. Thus the second hypothesis is given some support as the point of refractoriness of the second response includes only the 0 msec. ISI in Part B of Exp. IV, whereas the Regular series of Exp. III shows the PRP at 100 msec. as well as at 0 msec.

The curves for mean first and second response for Part C are quite similar to those for Part B. The rise in mean first response and the drop in mean second response latency as ISI length increases is significant ($p < .006$ and $p = .006$, respectively, two-sided). A sign test comparing mean first and second response curves at 50 msec. was not significant ($p > .05$, two-sided), but a Wilcoxon test was ($.02 < p < .05$, two-sided). The latter test indicates that when differences in the direction of the sign, as well as the magnitude of the differences, are taken into account, the mean first response is made with a shorter latency than the mean second response at 50 msec. This latter finding must only be provisionally accepted, since it is not legitimate to make multiple tests of significance on the same data. The difference between the two curves at the 0 msec. point is significant by a sign test ($p = .038$, two-sided). Since the curve for the mean first response was not flat, but rose significantly (sign test between 0 and 400 msec. ISIs on the mean first response curve, $p < .006$,

two-sided), the third hypothesis was not supported; instructing the Ss to be equally fast with both hands does not seem to affect the shape of the first or second response curve.

Discussion

It will be remembered that the rise of the mean first response curve as the ISI lengthens was statistically significant for Parts A, B, and C of Exp. IV, as well as for both the Regular and Random curves of Exp. III. The data from which this finding comes is thus based on four different studies involving 64 different Ss; the finding may be assumed to be a stable phenomenon, especially in view of Part C of Exp. IV, which explicitly tried to destroy it.

Helson (1964) found that when a tone follows a light (or vice versa) and the S is to respond only to the first stimulus, the following occurs: 1) When the second "signal" follows the first stimulus at 0 to 25 msec., the first (only) response is speeded up or facilitated; 2) At a 25-35 msec. ISI, the occurrence of the second signal appears to have no effect on the latency of the first response; 3) At greater than 50 msec. ISI the occurrence of the second signal acts to slow up the first (only) response. This was earlier explained within a competing response framework (Reynolds, 1964). The logic of the argument was that extremely short ISIs the double stimulation is perceived as a single, more intense, stimulus; it is known that RT decreases as the stimulus intensity is increased (Woodworth & Schlosberg, 1954).

There is support for this assumption of temporal summation (with increased phenomenal brightness) in Dember (1960), who cites the unpublished Ph.D. work of Clark (1958). Clark found complete temporal summation (using

double pulses of light from the same source) at ISIs up to 20 msec. At ISIs of 20 to 70 msec. the double pulses "...gradually became no more detectable than a single-pulse target (1960, p. 125)." Only with ISIs of more than 70 msec. were the two pulses seen as double. This compares very favorably with the work of Lindsley (1958), also cited by Dember. Lindsley found that two flashes of light had to be separated by about 73 msec. to be discriminated from each other when they were emitted from the same light-source. This should also be compared with Bartley's work (1951) which states that brightness enhancement is greatest at 10 cycles per second (analogous to an ISI of 100 msec.) with a light-to-dark ratio (the length of time each phase lasts) equal to unity.

The psychophysical groundwork is laid. At quite short ISIs, perhaps of 100 msec. or less, one may posit that the double stimulation is: 1) Perceived as single, or 2) That brightness enhancement occurs. The net effect of either of these is the same: a decrease in latency of the first response. If this is the case we would reasonably expect that a comparison of the mean first response for the ISIs at 200 and 400 msec. would not be statistically significant. Sign tests were computed for the appropriate data of Parts A, B, and C of Exp. IV, and for the Random and Regular series of Exp. III. Of the five sign tests, only the one for Part B was significant ($p = .038$, two-sided). Thus partial support is given for the psychophysical interpretation of increase in mean latency of the first response in the double-choice paradigm.

An alternate explanation is that at short ISIs a greater degree of physiological arousal occurs in maintaining the pacing of responses, i.e., that the S gets more "churned up" when two events occur in quick succession, and thus responds more quickly.

Although all three parts of Exp. IV had complete temporal and event certainty, results in Part A differed from those of Parts B and C. Ss in Part A gave no evidence of refractoriness; Ss in Parts B and C gave some evidence of refractoriness at a 0 msec. ISI, and possibly at a 50 msec. one as well.

If the net effect of temporal uncertainty is to increase the latency of the second response at "short" ISIs, the finding of refractoriness in Parts B and C is puzzling, for these conditions had temporal certainty. There are two main differences between the Ss in Part A on the one hand, and Parts B and C on the other: 1) In Part A the Ss received one and only one ISI throughout trials. In Parts B and C the Ss received all ISIs, though ISIs were constant within a block of 10 trials; 2) Ss in Part A received 100 trials at the same ISI, while those in Parts B and C received a total of 20 trials at the same ISI. 1) and 2) above are not identical. 1) refers to differences in the number of ISIs, while 2) refers to differences in the number of trials per ISI. Although the effect of 1) might be to somehow increase temporal uncertainty as blocks of trials progresses, and although this might "explain" the refractoriness in Parts B and C, the flavor is decidedly ad hoc. The second difference between Ss is analogous to the difference between "well-practiced" and not "well-practiced" Ss. Ss in Part A are much more "well-practiced" than those in Parts B and C for any single ISI. But thinking about this difference in terms of "practice" may obscure rather than enlighten.

The term "practice effect" as an explanation for improvement over trials (or across conditions, as in the present experiment) is not really an explanation, but a label. Why an increase in trials should bring about improvement is not explained. As a first attempt in explaining why Ss in

Part A should not have the second response delayed, one can perhaps return to the quotation from Berlyne (1960), cited above. Let us assume that at the beginning of the trials the first and second responses compete indirectly with each other due to the arousal of R_2 . With repeated elicitation of R_2 (presumed wholly incompatible with R_1), R_2 may be extinguished. If this is the case the "practice effect," i.e., decrease in latency over blocks of trials, should only affect the second response. The mean speed of the first response would be wholly unaffected by the extinction of R_2 . In order to check this hypothesis, mean first and second RTs over blocks of 20 trials were averaged for Ss at each ISI in Part A. (The 0 msec. group was excluded because in this group there is no "first" response.) Curves for the mean first and second response as a function of increasing number of trials are plotted in Figure 7.

It will be noted that the curve for the mean first response is a shallow U-shaped curve, whereas the curve for the mean second response decreases at each successive block of 20 trials. Sign tests on the difference between Blocks 1 and 4 and Blocks 1 and 5 on the mean first response curve were not significant ($p > .05$, one-sided). A sign test on the difference between Blocks 1 and 5 on the mean second response curve was highly significant ($p = .011$, one-sided). The prediction made above is thus borne out, and support is given for the "extinction of competing responses" explanation. Returning to the discussion of hypotheses made for Part A of Exp. IV, one can see that the original formulation was in error. The double-choice task elicits two responses, not one composed of two part-reactions. Competing responses do appear to form to the second response, and these competing responses are apparently extinguished over time.

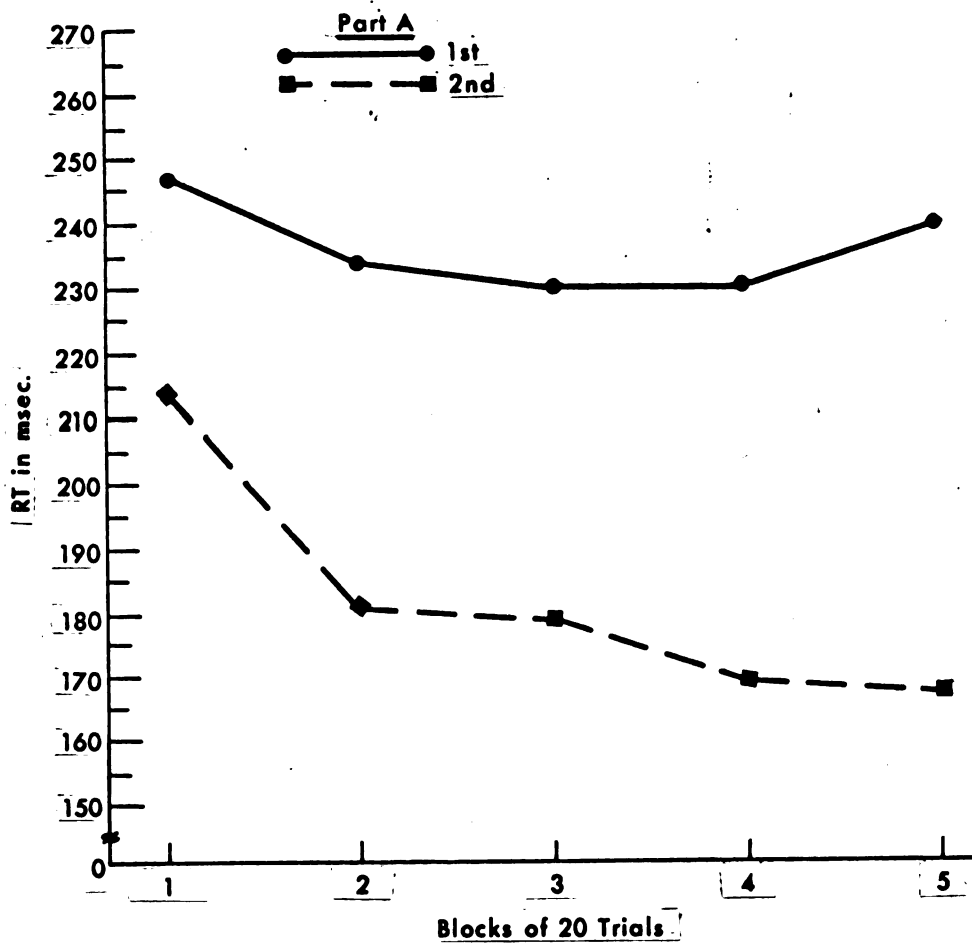


Figure 7. Reaction Time of 1st and 2nd Response as a Function of Blocks of Trials (Experiment IV-Part A).

Figure 8 (see p. 63) presents an analogous graph for the data of Part B. Note that the curves for both the mean first and second response rise slightly over blocks of 20 trials. Any "practice" effect associated with the second response is certainly at a minimum. This is additional evidence that in Part B a different process (or processes) is involved. In Part B there appears to be no extinction of the competing response R_{-2} , and consequently, the PRP is found at the 0 msec. ISI, and the "crossover" effect of the curves for mean first and second response is obtained.

When data is likewise plotted for the analogous comparison in Part C, identical results are obtained. Both the mean first and second responses have longer latencies after the sixth block of 20 trials than after the first, providing further substantiation of the belief that the major factor influencing the relative shapes of the curves in Part A vs. those of Parts B and C is the presence or absence of R_{-2} in competition with R_2 .

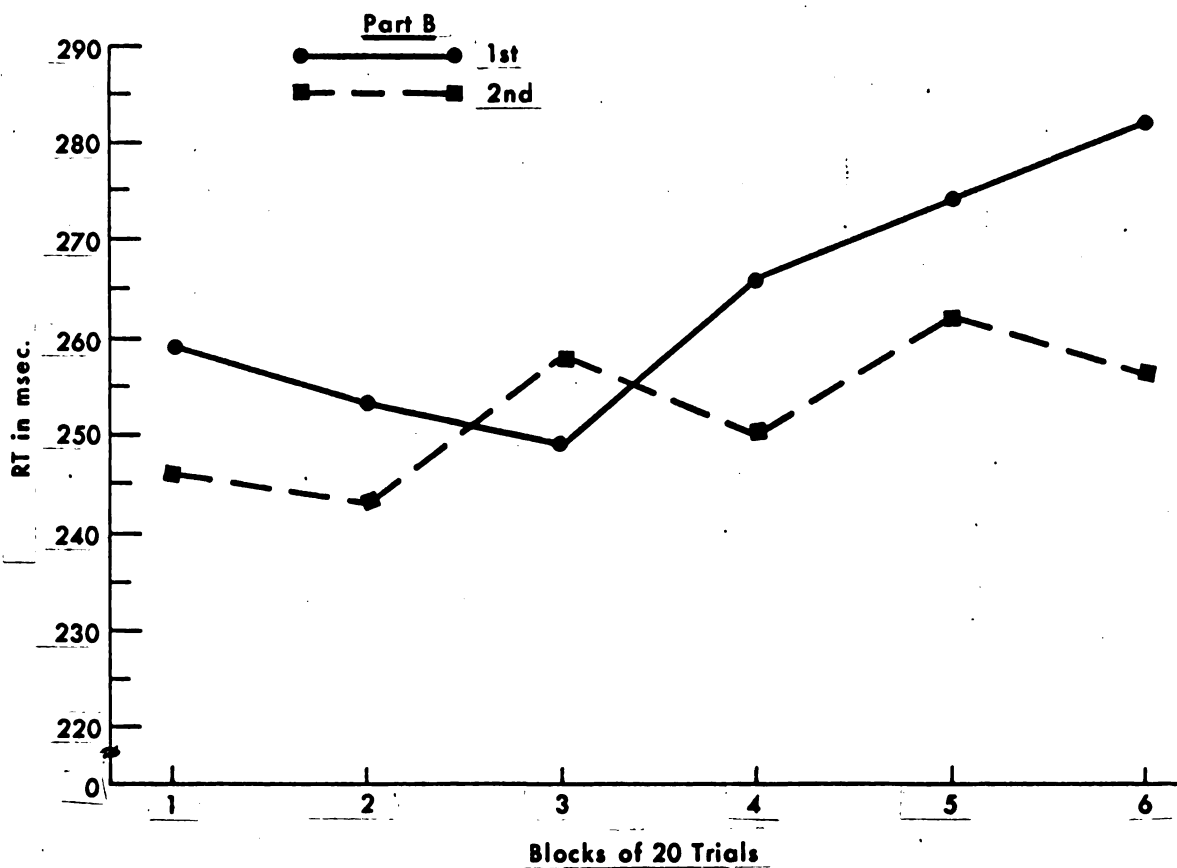


Figure 8. Reaction Time of 1st and 2nd Response as a Function of Blocks of Trials (Experiment IV-Part B).

GENERAL DISCUSSION AND CONCLUSIONS

The effect of event uncertainty in combination with temporal certainty was seen to result in generally longer latencies of response to both stimuli in the two-choice task, using unisensory stimuli. An attempt to train a prepotent response by means of probability learning was unsuccessful (Exp. I & II). The effect of temporal uncertainty in combination with event certainty was seen to result in longer latencies of the second response at the short ISIs - the Psychological Refractory Period. In general, latencies were shorter for both responses in this latter condition (Exp. III). The effect of complete temporal and event certainty was examined in conditions analogous to having "well-practiced" vs. not so "well-practiced" Ss compared on latencies of response. The "well-practiced" Ss had significantly shorter latencies than did the "less well-practiced" group (Exp. IV).

The results were generally in line with a theoretical position which explains delays in responding as due to the arousal of competing responses. Two types of delay were seen to have different antecedents: 1) Delay of both responses, due to the experimental combination of event uncertainty and temporal certainty; 2) Delay of the second response at short ISIs, due to the experimental combination of event certainty and temporal uncertainty. The second response was also found delayed, to a lesser degree, in conditions where complete event and temporal certainty were combined with relatively few trials.

The general explanation of these delays follows Berlyne's (1960) discussion: Making the first response (R_1) leads to the arousal of a response which competes with the second response; this response is labeled R_{-2} , and the second response is labeled R_2 . Given event uncertainty and

temporal certainty (Exp. I & II), the S must keep both responses (right-hand and left-hand) maximally prepared if he is to respond quickly to the onset of the stimuli. This accounts for the increase in latency to both stimuli, for the occurrence of either stimulus arouses responses associated with each stimulus. These responses are presumed to indirectly (via arousal of R_{-2}) compete with each other. Since the left-hand and right-hand stimulus-orders were randomly presented in Exp. I & II, there is no possibility for R_{-2} to be extinguished by the repeated elicitation of R_2 , since R_2 randomly changes over trials from a left-hand to a right-hand response. Thus R_2 is delayed across ISIs due to the inhibitory effects of R_{-2} . R_1 was somewhat longer than R_2 in latency in both Exp. I & II, but this difference was not significant.

Where events are certain (Exp III & IV), the first response is not delayed, and latencies decrease when compared to uncertain event conditions (Exp. I & II). The second response is delayed at short ISIs due to the arousal of R_{-2} , and there is a clear cross over of mean first and second response curves: R_1 increases and R_2 decreases in latency as the ISI lengthens. The increase in R_1 was thought due to either temporal summation of stimuli or brightness enhancement, or possibly increased physiological arousal at the short ISIs - at or below 100 msec. The decrease in R_2 latency was thought adequately explained by the extinction of R_{-2} through the repeated elicitation of R_2 .

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