SEQUENTIAL EFFECTS IN SERIAL REACTION TIME

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SUMMARY

In serial reaction time experiments it is possible to separate out the reaction times for responses to a stimulus which is the same as that on the previous trial and to compare these times with those for responses to stimuli which are different from the stimulus which occurred on the previous trial. The experimental findings concerned with such sequential effects reported in the literature are discussed in terms of the four main variables which have been investigated, and an attempt is made to evaluate the explanations that have been put forward to account for sequential effects. The necessity is stressed for more detailed analyses of data than have usually been attempted in elucidating the nature of these effects.

Following this discussion, a series of experiments is reported in which a 2-choice task was used with an analysis procedure which allowed comparisons of the reaction times to all possible combinations of events in sequences up to and including 5. Effects are studied of interstimulus interval, stimulus-response compatibility, massed trials, instructions designed to deceive the subject as to the sequential probabilities employed, the probability of sequences of repeated stimuli and of sequences of alternated stimuli and prior preparation for particular events.

In further experiments using an 8-choice task, the data are analysed in such a way that the reaction times to each stimulus following every other stimulus can be compared. Variables investigated using this analysis are interstimulus interval, stimulus-response compatibility and prior preparation for a particular event or events.

The results generally confirm the need for detailed analyses of the data. Analysis of the 2-choice results show that reaction time to a stimulus is affected not only by the immediately preceding stimulus but by stimuli further back in the series, and support an explanation of the effects in terms of expectation and preparation.

Analysis of the 8-choice results showed that:

1) repetition of the previous stimulus did not always lead to a faster response,

2) responses to stimuli adjacent to those immediately preceding tended to be faster than to those more remote,

3) both of these effects, but more particularly the latter, depend upon the interstimulus interval, being greater the shorter the ISI. An explanation for these results is proposed which assumes that subjects locate the correct stimulus by seeking the nearest of three or four reference points: the ends of the display, the middle and if the interstimulus interval is short enough, the position of the last stimulus.

Overall the results for both the 2- and 8-choice experiments indicated that the manner in which the subject performed the task is flexible, that is, he uses slightly different strategies in responding to stimuli depending on

the instructions given and the experimental situation. An attempt is made to list some of the strategies which subjects can use and those which they do in fact seem to use under the different experimental conditions.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the text.

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CHAPTER I.

REPETITION AND ALTERNATION EFFECTS: FACTS AND GENERALISATIONS

In the application of information theory measures to choice reaction time (RT) studies, Hyman (1953) listed three ways in which the average amount of information accompanying the presentation of a single stimulus could be independently varied. These were by varying (a) the number of equiprobable alternatives from which it could be chosen, (b) the proportion of times it could occur relative to the other possible alternatives, and (c) the probability of its occurrence as a function of the immediately preceding stimulus presentation.

While Hyman's main interest was in the effects of varying uncertainty on the overall mean RT, he noted that, "whenever a stimulus was immediately followed by itself in a series, S seemed to respond unusually fast to it", and that, "an examination of the data showed that this phenomenon was quite marked for the situation with four or more alternatives and steadily declined until it disappeared or became slightly negative for the case with just two alternatives".

Subsequent studies in the literature have examined the effects of four main parameters. The results of these studies will be reviewed in the following sections.

1.1. Sequential Effects and the number of stimulus-response (S-R) alternatives

The tendency to respond faster to a stimulus which is the same as one preceding it, is now customarily referred to as a "repetition effect", while the opposite tendency, to respond faster to a stimulus which is different from the one preceding it is termed an "alternation effect".

Hyman's finding of the repetition effect for RT tasks with greater than 2 choices has been confirmed for 8-choice tasks by Hale (1969), Kornblum (1968), Rabbitt (1965, 1968), Hoyle & Gohlson (1968), for a 6-choice task by Keele (1969), for a 5-choice task by Leonard, Newman & Carpenter (1966), and for 4-choice tasks by Kornblum (1967), and Hoyle & Gohlson (1968), Smith (1968), Hale (1969), Kornblum (1969), Schvaneveldt & Chase (1969), and Remington (1971).

There are suggestions from several experiments reported in the literature that the repetition effect tends to be greater with more alternatives. Hyman's (1953) remark that concerning the repetition effect, "this phenomenon was quite marked with four or more alternatives and steadily declined until it disappeared or became slightly negative with the case with just two alternatives", has already been noted. Suggestions of an increase in the repetition effect from 2-choice to 4-choice to 8-choice are also contained in experiments by Hoyle & Gholson (1968), Hale (1969). Kornblum (1969), in commenting on changes in the differences between RTs to repetitions and alternations with increasing number of S-R alternatives notes a similar relationship in data replotted from an earlier experiment, Kornblum (1967). He also noted that "this increase, furthermore, appears to be primarily attributable to a far greater increase inthe RT for nonrepetitions than for repetitions, although both increase with increasing values of k", (where k is the number of S-R alternatives). The same changes in the RTs for repetitions and alternations are apparent in the data for Hoyle & Gholson (1968).

While repetition effects have been found for RT tasks involving more than 2 choices, the situation is by no means as clear when 2-choice tasks are considered. Some experimenters have found a repetition effect, for example, Bertelson (1961, 1963), Bertelson & Renkin (1966), and Remington (1969), while others have found an alternation effect, for example, Hyman (1953), Williams (1966) and Welford (1959). Others have found both in the same experiment by varying experimental conditions, for example, Hale (1967), Moss, Engel & Faberman (1967), Hannes (1968), Shaffer (1965), Entus and Bindra (1970).

The most important variable in determining whether a repetition or alternation effect is obtained in 2-choice tasks seems to be the inter-stimulus interval, a discussion of which follows in the next section.

1.2. Sequential effects and the interstimulus interval (ISI).

(1) Two-choice tasks. All the evidence to be discussed in this section will be taken from conditions in experiments

where 2-choice tasks have been used with compatible S-R arrangements and where the probability of a repetition in a sequence is the same as that for an alternation. The reason for this will be made clear in two following sections which will examine the effects of incompatible S-R arrangements, and of varying the probabilities of repetitions and alternations.

The first experiment directly concerned with the repetition effect was that by Bertelson (1961) who found a significant repetition effect with an ISI of .05 sec. but, using a different group of Ss, failed to find a significant effect using an ISI of .5 sec. In another experiment, Bertelson (1963) confirmed the finding of a repetition effect for an ISI of .05 sec. Kornblum (1967) also found a repetition effect with an ISI of 137 msec. and Hale (1969) with an interval of 100 msecs. In a later experiment, Bertelson & Renkin (1966) further examined the change in the repetition effect using 50, 200, 500 and 1000 msecs. In one condition, these different intervals were presented separately in blocks of trials; in another, they were presented together but randomly in the same block of trials. In both conditions a similar decrease in the repetition effect with increasing ISI was found, indicating that "the time course of the repetition effect seems to be independent of the time uncertainty regarding the arrival of the next stimulus".

In contrast to this finding, Williams (1966), found an alternation effect with an ISI of between 12 and 15 sec. Another experiment reporting an alternation effect with an ISI of 12 sec. is that of Moss, Engel & Faberman (1967).

Evidence indicating the importance of the length of ISI in explaining the discrepancy between these two findings was provided by Hale (1967) who, using 100, 600 and 2000 msecs., found a decrease in the repetition effect from the 100 to the 600 msec. condition, and an alternation effect in the 2000 msec. condition. Similarly, Entus & Bindra (1970) reported a change from a repetition effect to an alternation effect by increasing the ISI from 2 sec. to 10 sec. While these authors give no information concerning the changes in RTs to repetitions and alternations with increasing ISI, Bertelson & Renkin found that RTs to new signals became shorter and to repeated signals longer. However, examination of their data indicates that, for the regular interval conditions, there was little change in the RT for alternations, most of the change with increasing interval being due to an increase in the repetition RT, a result also found by Hale. This is in contrast to the effect of increasing the number of S-R alternatives where, as was pointed out in the previous section, the evidence suggests that the main effect is on the alternation RT.

Another difference in the experimental procedures used by Williams and by Moss, Engel & Faberman on the one hand, and Bertelson on the other, would seem also to be important in explaining the difference in results. Hannes (1968) noted that Bertelson used two lights and two keys, one operated by a finger of each hand, while both Williams', and Moss, Engel & Faberman's Ss used only one finger, either to move a lever switch to the right as one response and to the left as another, or to move from a home key to the appropriate response key. Hannes compared these two different response systems using the same stimulus display of two lights with an ISI of 15 sec. which was similar to that used by Williams. Using two fingers was found to produce faster repetitions and using one finger, to move from a home key to the appropriate response key, was found to produce faster alternations. An experiment reporting a change from a repetition to an alternation effect with increasing ISI is that of Entus & Bindra, who found this using ISIs of 2 sec. and 10 sec. with a 2-choice task involving a one finger response system. However, comparing the results of Entus & Bindra for a 2 sec. ISI with those of Hale (1967), who used a two finger response system for the same interval, shows Hannes' result to be of little explanatory value; the two different response systems produced opposite results to those which would be predicted by Hannes, the one finger system producing a repetition effect, and the two finger system an alternation effect.

To complicate the situation further, Remington (1969), using a response system similar to that of Bertelson, found a repetition effect with an ISI of 4 sec. and Schvaneveldt & Chase (1969), using similar 2 choice tasks and ISIs of either 1, 2.5 and 8.5 sec., or .1, .5 and 1.0 sec., failed to find a repetition effect at the low ISIs or any change in the sequential effect with increasing ISIs.

In commenting on this lack of change, Schvaneveldt & Chase mentioned that "experiments reporting a decrease in the repetition effect with (increasing ISI) have only used two choice lights-buttons or numbers-buttons codes (Bertelson, 1961; Bertelson & Renkin, 1966; Hale, 1967)". The "lights-buttons" and "numbers-buttons" codes refer to arrangements in which buttons were pressed in response to either two lights or two numerals. Although they did not say exactly how this might be expected to produce the change in question, presumably they were referring to the compatibility of the S-R arrangement as a possible factor. However, they also used a numbers-buttons code and failed to find a change in the repetition effect with increasing ISI. Eichelman (1970) also discusses the suggestion that Schvaneveldt & Chase's failure to find a repetition effect at low ISIs might be due to the very high S-R compatibility of the task where the correct key pressed was illuminated as a signal. However, he points out that in his experiment a highly compatible task was used, yet still produced a large repetition effect at low ISIs. He argues this may well be due to the use of a symbolic display, since other experiments using symbolic displays have also produced repetition effects at low ISIs; for example, Hale (1967), Bertelson & Renkin (1966), Rabbitt (1967), and Bertelson (1965). However, Bertelson (1961, 1963), did not use a symbolic display yet still found a repetition effect and a decrease in the repetition effect with increasing ISI. Thus, although compatibility of the S-R relationship and the use of symbolic displays may be important factors determining sequential effects, neither seems capable of explaining Schvaneveldt & Chase's result.

Another possible factor which could be important in explaining Schvaneveldt & Chase's result is the number of trials given. For the condition in which ISIs of 1, 2.5 and 8.5 sec. were compared, only 135 trials were given. In the other compatible S-R arrangements only 300 trials were given. This compares with the 2000 practice trials and 6000 test trials used by Bertelson (1961), the 1200 practice trials before the 300 test trials used by Bertelson & Renkin (1966), and the 1000 test trials for the 100 and 600 msec. condition and the 500 trials for the 2 sec. condition used by Hale (1967). As against this, Entus & Bindra (1970) only used 20 practice trials and 80 test trials in each ISI condition and found a change from a repetition effect to an alternation effect with increasing ISI. But in their experiment the S had to respond to two circular patches of white light which differed only in diameter, one being 7/16 inch the other 6/16 inch. The Ss had to press one key labelled "big" if the larger of the two lights appeared, and another labelled "small" if the smaller appeared. Since the screen upon which the light patches were projected was situated 3 feet from the S, the task would appear to be quite a difficult one which, on the basis of evidence to be presented concerning the effects of incompatible S-R arrangements in a following section, might be expected to accentuate sequential effects.

If Entus & Bindra's results could be explained in terms of the difficulty of the task, it might be thought worthwhile to consider the difficulty of the tasks of the other two anomalous results; that is, those which found repetition effects with ISIs of greater than 1 sec. However, the tasks for both Remington (1969) and Hannes (1968) appear from their description to be quite straightforward and no more difficult than those used in the other experiments considered, although Remington (1969) did use both a red warning light and a green light to give knowledge of a correct response. Possibly the Ss, paying attention to these two, may have suffered some distraction which caused a repetition effect.

In summary, generally in 2-choice compatible tasks with repetitions and alternations equiprobable, repetition effects would appear to occur with ISIs of less than approximately 1 sec. and alternation effects with ISIs of greater than 1 sec.

There are several anamolous results, only one of which might be explained in terms of the use of an inadequate number of trials.

(2) Greater than 2-choice tasks. In both experiments considered in this section, all stimuli were equiprobable and randomly presented. While no alternation effects have been reported for RT tasks with greater than 2 choices, several experiments have examined possible changes in the repetition effect with increasing ISI. Keele (1969) used a 6-choice compatible task and found a repetition effect which did not change across three ISIs used; 2, 4 and 8 sec. However, only 120 trials for each ISI were given.

A study which found a decrease in the repetition effect from a 2 to a 6 to a 10 sec. ISI was that of Smith (1968). A 4-choice task was used in which Ss had to respond using push buttons to either a "1" or a "2" which could either be red or green. If red the S responded with his left hand; if green with his right. If the number was a 1, S responded with the forefinger of the appropriate hand depending on whether the signal was red or green, and if 2, with the middle finger of the appropriate hand, again depending on whether the signal was red or green. Although only 96 trials per ISI were given, as with the experiment by Entus & Bindra (1970), this task would seem to be substantially more difficult than the straightforward arrangement used by Keele (1969).

Hence it would appear that with 2- and greater than 2-choice tasks the evidence generally suggests a decrease in the repetition effect with increasing ISI. However, the number of trials given and the difficulty of the task appear to be important factors qualifying this conclusion. Variations in the difficulty of the task and the resulting sequential effects will be dealt with in the following section.

1.3 Stimulus-Response Compatibility

One way in which the difficulty of choice RT tasks has often been increased is by impairing the compatiblity between stimulus and response.

Bertelson (1963) compared three conditions; (i) direct (D) in which the S responded using two keys, pressing the left key in response to the left of two horizontally placed lights and the right key in response to the right light; (ii) crossed (C) where the same light-key arrangement was used, except that the S now pressed the left key in response to the right light and the right key in response to the left light; (iii) perpendicular (P) where the two lights were arranged vertically, with the two possible light-response combinations being high-right/ low-left and high-left/low-right. The ISI was .05 sec. In addition, after each of these main conditions which consisted of 11 runs of 50 responses, Ss were asked to do 2 runs with the opposite S-R relationship; that is C after D, D after C and one P combination after the other.

The results show that for the main conditions the repetition effect was much larger in both the C and P conditions than in the D condition. In addition, decreasing the S-R compatibility produced much larger increases in the RT to the new signals than to the repeated signals. This result parallels the findings of greater changes in RTs to the new rather than to the repeated signals with increase in the number of S-R alternatives, and contrasts with the increase of RT to repetitions rather than alternations with ISI in 2-choice tasks. The two runs of each session in which the S-R relationship was reversed were always found to yield larger repetition effects than the runs which preceded them, although the effect was small and not significant for the crossed condition. It was suggested that the smallness of the effect in this condition was due to the fact that performance in the crossed condition is permanently hampered by interference from the very familiar relationship which defines condition D, so that no short term interference could be effective. In the two conditions where there were significant effects, again the RTs to new signals were mainly affected. In a second experiment reported in the same paper, Ss completed a 4-choice compatible S-R task with the numbers 1, 2, 3 and 4 as stimuli and four keys, the first key on the left being pressed in response to 1, the second to 2, and so on. The results of this task were compared with an incompatible arrangement using the same lights and keys but with numerals corresponding to the keys from left to right, 3, 2, 4 and 1. As for the 2-choice task, there was a substantial increase in the repetition effect due to the incompatible arrangement, and again the RTs to new signals increased much more than those to repeated signals, although the latter also increased significantly.

A similar experiment using a 4-choice task was that of Schvaneveldt & Chase (1969). Three ISIs were used; .1, .5 and 1.0 sec. The first task consisted of pressing lighted buttons, a very compatible arrangement. The second and third were similar to those of Bertelson, with the correspondence between numbers and buttons being ordered and scrambled respectively. There were no significant changes due to ISI but there were increases in the repetition effect as incompatibility increased. However, unlike Bertelson's results, the overall mean RT for the third task appears to be slightly less than that for the second, the increased repetition effect being due to faster repetition RTs and slower alternation RTs. Schvaneveldt & Chase also examined higher order sequential effects; that is, not just the effects of the immediately preceding stimulus but also the effects of stimuli prior to that. These effects were minimal for the first task and they noted that "with a highly incompatible scrambled numbers-buttons code, a single repetition produces a dramatic maximal facilitation in RT". But for the second task they found "a repetition effect which depends on at least two repetitions before RT is greatly facilitated".

Williams (1966) compared a 2-choice task with a compatible S-R code and a 10 sec. ISI with a task in which the same signal and response apparatus was used but in which the *S*s had to respond depending on whether the present stimulus was the same as the previous stimulus or different; for example, moving a lever left to signals which were repetitions and right to changed signals or alternations. In this way it was hoped to determine whether observed sequential effects depended more heavily on the patterning of the input or of the output by comparing the RTs for the 4 possible conditions - of signal repeated or changed combined with response either repeated or changed. Williams found that RTs for this incompatible arrangement were approximately twice as high as those for the compatible arrangement, indicating that *S*s found the incompatible task extremely difficult. It was hypothesised that if the sequential effects observed under the compatible arrangement were due primarily to either the input or the output, this would be shown in significant differences between latencies of one but not of the other. There were, however, no significant overall differences between either repeated or changed responses or in responses to repeated or changed signals. What was found was that RTs were smallest when both signals and responses changed or both signals and responses were repeated, and longest for combinations of repeated signal and changed response or vice versa.

A task somewhat similar to that of Williams was used by Shaffer (1965). Two stimulus lights (M) and two response keys (R) were used, but in addition to the two lights which were arranged horizontally, there was an illuminated cross between them of which the vertical and horizontal limbs (I) could be lit independently. The horizontal line (H) defined the homolateral mapping of M and R, and the vertical line (V) a contralateral mapping. The conditions of most interest to the present discussion are those in which (i) Ss had a simple homolateral or compatible S-R mapping with the horizontal line always appearing in the display (2H); (ii) the mapping was contralateral with the vertical line always appearing in the display (2V); and (iii) one of the two lights (M) and either (H) or (V) came on simultaneously on each trials (2I, 2M), so that on some occasions there was a homolateral mapping, on others a contralateral. The results showed that there was a repetition effect when I was variable and an alternation effect when it was fixed, even with contralateral mapping, and even although there was a greater overall mean RT for the 2V than for the 2H condition. Thus, although increasing the difficulty from a homolateral to a contralateral mapping did not decrease the alternation effect found with the former, increasing the difficulty of the tasks still further to the use of a variable I did produce a repetition effect. Shaffer comments that, in the light of Bertelson's (1961) finding of a decrease in the repetition effect from an ISI of .05 to one of .5 sec., it seems that "the transition effect favouring repetitions is a joint function of inter-trial interval and any factor affecting difficulty of the task". However, although there was no apparent difference between the size of the alternation effects of the 2H and 2V conditions, it was noted that the overall mean RT was larger for the 2V condition. If a larger overall mean RT is indicative of a more difficult task, the lack of difference in the alternation effects between the 2V and 2H conditions remains anomalous.

The increased difficulty of the task referred to by Shaffer may be taken to include not only decreased compatibility but also the larger the number of S-R alternatives as both would tend either to increase already existing repetition effects or to change existing alternation effects into repetition effects. The anomalous result of Entus & Bindra (1970) referred to in the previous section may now be seen to be explicable in terms of the effect of the greater difficulty of the task which they used.

Another type of S-R incompatibility is that of mapping two or more stimuli onto one response. However, it seems more appropriate to deal with these experiments in a later section concerned with the role of the repetition of the stimulus and of the response in determining the overall repetition effect.

1.4. Probability of repetitions and alternations

So far almost all the evidence considered has been taken from experiments where the probability of repetitions and alternations has been equal. As was pointed out initially, it is possible to alter the sequential dependencies in such a way as to produce unequal probabilities of repetitions and alternations. This can be done either with or without keeping the number of S-R alternatives equiprobable.

Bertelson (1961), in addition to an equiprobable (or random RAND) repetitions/alternations condition also used sequences in which the probability of repetitions and alternations were 75% and 25% respectively (REP) and vice versa (ALT). In all sequences the two stimuli were equiprobable. Using an ISI of .05 sec., he found that the REP condition produced the fastest overall mean RT and the ALT condition the slowest. In addition he found a difference of 90 msec. in favour of repetition RTs in the REP condition, of 29 msecs. in favour of repetitions in the RAND condition and of 21 msecs. in favour of alternation RTs in the ALT condition. The two repetition effects diminished when a time lag of .5 sec. was used but the alternation effect in the ALT condition increased. All effects whether repetition or alternation were significant except that for the RAND sequence with the longer ISI.

Moss, Engel & Faberman (1967) used a similar task to that of Bertelson (1961) except that they used an ISI of 12 sec. An alternation effect, albeit not significant, was found for their RAND condition, a significant alternation effect for the ALT condition, and a small nonsignificant repetition effect for the REP condition.

It would thus appear that a bias in the proportions of repetitions or alternations at least of the order of that used in the above two experiments leads to a lower RT to the particular type of stimulus which is favoured. This must therefore be taken into account when considering the effects of ISI on sequential effects. For example, Hyman (1953) found an alternation effect with a 2-choice compatible task using an ISI of approximately 10 sec. (as estimated by Bertelson, 1961). This could be taken to support the tentative division of repetition effects in 2-choice tasks with ISIs below approximately 1 sec. and alternation effects above 1 sec. However, the sequence used in Hyman's task was heavily biassed in favour of alternations. Similarly, Welford (1959) found in a 2-choice task that RTs to alternations were faster than to repetitions but again there was a heavy bias in the sequences used in favour of alternations.

It should be remembered that the above experiments were all concerned with 2-choice tasks. With greater than 2 choices, of course, random sequences will result in greater numbers of alternations from one stimulus to another than repetitions of the same stimulus. Thus in a 4-choice task, there would be only 25% repetitions. Yet repetition effects have always been reported for greater than two choices. In view of the results reported above, this may imply different causes of the repetition effects in 2- and greater than 2-choice tasks.

Leonard, Newman & Carpenter (1966) studied the effects of stimulus frequency imbalance on sequential effects in a 5-choice task in which the numbers 1, 2, 3, 4 and 5 were responded to in a compatible arrangement by the five fingers of the right hand. There were two main conditions, one in which the number 3 occurred 68% of the time, the other numbers each 8%, and the other in which the number 3 occurred 44% of the time and the others each 14%. In addition, the data from each condition were divided into three further categories in which the proportion of stimulus 3 was either high, approximately equal, or low compared with the overall proportion of that stimulus. Also 7 trials of 50 stimuli each were transplanted from the 68% condition and appeared in exactly the same ordinal position in the 44% condition. The aim of the experiment was to determine whether Ss responded to biassed sequences on the basis of long or short-term sampling. It was argued that if the latter were the case there should be identical results for the 7 common trials in each condition, but if long term sampling was used, these results would be different. Sequential analysis of runs of stimulus 3 showed a strong repetition effect and the analysis of response times for each stimulus showed that while those for stimulus 3 were shortest in both conditions, they varied with the amount of local bias, being shortest with the high local bias and longest with the low local bias. It was noted for the runs of stimulus 3 that RTs decreased as the run increased from 1 to 2 to 3 repetitions of stimulus 3, but that thereafter the RT remained relatively constant. It was also noted that the variability of the means for these responses decreased as the run length increased.

The analysis of the 7 identical trials indicated that although the overall mean RT for the 68% condition was less than that for the 44% condition, the difference between them was not significant. The decrease in RT with increasing length of run was also the same for both conditions. However, RTs to stimulus 3 and for runs of stimulus 3 were significantly less in the 68% condition. The authors concluded that while the different results for the various local bias conditions indicated "short-term sampling", the relatively stable pattern of responding, which was identical within each condition regardless of the level of bias, and particularly in the "identical trials", provided evidence for the role of "long-term sampling". The negative correlation between RT and the amount of local bias was accounted for in terms of the fewer responses to biassed stimuli in the low local bias condition and the fact that these would be made up of the RTs from shorter runs of stimuli. These times would tend to be less than those in the high local bias condition which would be taken from longer runs.

Remington (1970) in a methodological consideration relevant to the above experiment discusses data from a previous experiment (Remington, 1969) in which two 2-choice conditions were compared, one in which the two stimuli were equiprobable and the other in which one of the stimuli occurred 70% of the time. Repetition and alternation probabilities were nearly equal for both conditions. RT was plotted as a function of rank in a run of repetitions up to 4. Plotting the data in this way led to similar decreases in RT as the repetition sequence increased in length in both conditions, except that the initial decrease from alternation RTs to the first repetition appeared to be larger for the 70:30 condition. However, plotting the data for each component of the 70:30 condition separately, indicated that the apparent larger repetition effect was due to averaging over the two components that make up this condition; while both 70 and 30% components contribute equally to the overall alternation RT, the 70% component, with a greater number of repetitions and faster RTs, largely determines the overall mean RT for the initial repetitions. Remington adds that "failure to recognise this fact would also lead one to overestimate the relative importance of the first repetition (that is the repetition effect) and underestimate the role of additional repetitions" and cites the above mentioned experiment of Leonard, Newman & Carpenter (1966) as an example of a misleading interpretation (they reported "a strong repetition effect") resulting from the process of averaging over components. In particular, Remington recommends that in choice RT tasks involving more than two choices, where it has been customary to pool all nonrepetitions of signals to obtain a single value for alternations, "the appropriateness of such averaging should be determined by a detailed sequential analysis of each nonrepetition component".

In a subsequent experiment, Remington (1971), this form of analysis was carried out on data from a 4-choice task using four lighted numerals, 1, 2, 3, 4, and four keys in a compatible arrangement. In one condition all stimuli were equiprobable. In the other, stimulus light 1 occurred 40% of the time and the others each 20% of the time. The repetition effect for stimulus 1 in the equiprobable condition was found to vary depending on whether it was preceded by stimulus 2, 3 or 4. Higher order sequential effects were also found of stimuli two before the stimulus to which the S was responding. In the 40:20:20:20 condition, the RT to stimulus 1 (40%) was found to be lower than those to the other stimuli, as expected. Unlike the data examined in the 1970 paper, however, where an apparent larger overall repetition effect was found to be due to the averaging of conditions, a larger repetition effect was observable in the present experiment for stimulus 1 when compared with the equiprobable condition even when no averaging took place. An interesting finding with implications for an explanation of sequential effects was that the RT to stimulus 2 was faster than the RT to stimulus 3 in the 40:20:20:20 condition, although they had been the same in the equiprobable condition. This was taken by Remington to suggest that the Ss' search pattern in the 40:20:20:20 condition began at the left (that is stimulus 1) and proceeded to the right.

In conclusion the evidence reviewed suggests that the size of the repetition or alternation effect varies directly with the probabilities of repetitions or alternations respectively, given that the stimulus alternatives are equiprobable, and given the size of the sequential effect (whether repetition or alternation) in the situation with repetitions and alternations equiprobable. That is, altering the probability of repetitions and alternations from equal will change the sequential effect (whether repetition or alternation in the equiprobable situation) in the direction of the one with the greater probability (Bertelson, 1961 as compared with Moss, Engel & Faberman, 1967). The repetition effect may also vary with the relative probabilities of occurrence of each stimulus but, as Remington (1970) has pointed out, care must be taken that this is not due to averaging over the alternation RTs.

1.5. Summary

From the foregoing review of the empirical findings in the literature it would appear that generally:

(1) Repetition effects occur for greater than 2-choice tasks and the magnitude of them increases with the number of S-R alternatives. The main increase in RT with number of alternatives is in responses to alternations.

(2) Repetition effects generally occur in equiprobable 2-choice tasks with ISIs of less than approximately 1 sec., while alternation effects occur with ISIs of greater than 1 sec. The repetition effects tend to decrease and even to change to alternation effects with increasing ISI, the main change in RT being in the responses to repetitions.

(3) The repetition effect increases with decreasing compatibility of the task, the main increase in RT being on responses to alternations.

(4) The size of the repetition or alternation effect is directly related to the probability of repetitions or alternations in the sequence, given the size of the sequential effect whether repetition or alternation for the same situation with repetitions and alternations equiprobable.

Of these four summary statements, statement 2 would seem to be the most tentative at this stage, particularly concerning the change in the repetition effect with increasing ISI.

If decreasing the S-R compatibility and increasing the number of S-R alternatives are taken as factors increasing the difficulty of the task, the effects of three of the variables examined can be summarised in terms of Shaffer's (1965) suggestion that "the transition effect favouring repetitions is a joint function of intertrial interval and any factor affecting difficulty of the choice".

Little at the moment can be said about the nature of the alternation effect except that it seems to occur only in 2-choice tasks with long ISIs, and changes with the probability of alternations in the sequence, in this way being similar to the repetition effect.

CHAPTER II.

REPETITION AND ALTERNATION EFFECTS: ATTEMPTS AT EXPLANATION

The aim of the present chapter is to review briefly those experiments concerned with explanations of sequential effects in choice RT tasks. Following Welford's (1960) analysis of the human operator into subsystems, the question of the location of sequential effects could be answered in three ways. The repetition effect could be due primarily to:

(1) repetition of the stimulus, or

(2) repetition of the response, or

(3) repetition of some central process mediating between the stimulus and the response.

Similarly, the alternation effect could be due primarily to either stimulus, response or central processes.

2.1. Stimulus or response processes?

Williams (1966) in the first of a series of 2-choice experiments found an alternation effect. In the second experiment, the possible contribution of what she termed "sensory receptive" fatigue was examined. It was hypothesised that "if the observed sequential effects were due (in the case of visual signals) to retinal fatigue, which might produce poorer reception of the repeated signals than of changed signals, then the effect should be observed when successive signals are delivered to the same eye but should not be observed when successive signals are delivered to different eyes." The results of carrying out this procedure were that the observed sequence effects could not be accounted for by sensory receptive fatigue.

In an attempt to separate out the stimulus and response components in the repetition effect, Bertelson (1965) used a task in which equiprobable signals were mapped into two responses, two signals to each response. Such a task allows three categories of RT: the relationship of a stimulus and its response to the preceding stimulus and response can be one of "identity", (same signal, same response), of "equivalence", (different signal but same response) or of "difference" (different signal, different response). If only repetition of the signal is important then "identical" RTs should be faster than "equivalent" and there should be no difference between "equivalent" and "different" RTs. If, however, only repetition of the response is important, then "equivalent" RTs should equal "identical" and both should be faster than "different". An intermediate value for the "equivalent" RTs between those for "identical" and "different" would implicate repetition of both the signal and the response. Bertelson found that while "identical" RTs were slightly less than "equivalent", implying some effect due to repetition of the signal, the main difference in RT was between "different" and "equivalent", implying that the main effect was due to repetition of the response. It was also noted that the vast majority of errors consisted of repeating the response when the other response was required.

Smith (1968) pointed out that Bertelson in the above experiments used the numerals "2" and "4" as stimuli for the left hand response and "5" and "7" for the right. Thus it is possible that Ss could code the stimuli as "even number respond with left hand, odd number respond with right", and so produce an apparent response effect. In order to eliminate this possible confounding, Smith used a number-colour code, left key to be pressed for either a red "1" or a green "2" and right key for either a green "1" or a red "2". The results showed that while "identical" responses were the fastest, "equivalent" responses were in fact slower than "different". Smith concluded that this suggested not a peripheral but a central effect, and that the fact that "equivalent" RTs were slower than "different" might have been due to a slight reluctance on the part of the subject to make the same response to a new stimulus that he had just made to a different stimulus.

The difference between Bertelson's and Smith's results can be resolved by the findings of Rabbitt (1968). Four different mappings of stimuli (S) to responses (R) were used; 2R/4S, 2R/8S, 4R/8S, 8R/8S. Ten runs of 301 signals each were given and results were examined for the second and tenth runs. For the second run, it was found that in all conditions, RTs for "identical" transitions were less than "different" transitions, that for the 2R/4S, 2R/8S and 4R/8S conditions, "identical" RTs were less than "equivalent", but there was no significant difference between "different" and "equivalent" RTs in any condition. This result was similar to that of

Smith who used only 200 trials plus 12 practice trials. For the tenth run, however, while again "identical" RTs were less than "different", the latter were significantly greater than "equivalent". In the 2R/4S and 4R/8S conditions "equivalent" RTs were significantly greater than "identical". Since Bertelson (1965) used 500 trials, Rabbitt's results suggest that practice is important.

It is possible that Smith's hypothesis of inhibition in making the same response to a signal different from that immediately preceding, might be extended to cover these results by assuming that inhibition becomes less with practice. Rabbitt, however, interprets his results in terms of models derived from computer programs for character recognition. The computer routines considered are (1) parallel routines where a set of X_t independent tests are made on the input simultaneously to establish whether or not the input can be classified as one of X_t different states; (2) a serial routine where the X_t independent tests are made one at a time in succession; and (3) a hybrid routine where X_t tests would be made successively in batches of parallel tests for N different subgroups of states. Each of these could also be further classified as exhaustive or self-terminating, the first where all possible X_t tests are made before the input is classified and the second where tests continue only until any test or set of tests is successful before classification of the input.

Exhaustive routines could be discounted due to the existence of the repetition effect since no difference between RTs would be predicted if all tests were performed either in parallel or serially before a decision is made. The results in fact suggest a serial self-terminating routine, with the last stimulus checked first, but the data did not allow a decision between its being a hybrid or not. In either case the change in RTs across trials would have to be explained in terms of modifications of the perceptual strategies as the S learns the way in which the signal ensemble is partitioned. For the serial self-terminating routine, Ss might adapt the order of testing to coincide with the experimenter's partitioning of the ensemble of signals; for the hybrid self-terminating routine practice might result in modification of the subsets of parallel tests until they coincide with the partitioning of the ensemble.

In order to explain the above modification of the S's strategy so that "equivalent" responses become quicker over time, Rabbitt suggested that any reduction in time taken for perceptual identification of equivalent signals might allow the S to benefit from repetition of the motor components of the response. The absence of the repetition effect on the "equivalent" transitions early in practice could then be due to identification and classification taking so long that successive responses are too widely spaced in time for maximum facilitation. It is clear that Rabbitt's explanation assumes both a stimulus and a response effect; signals are classified in a particular order which may result in a motor facilitation effect.

A somewhat similar experiment by Eichelman (1970) using ISIs of 200 - 700 msecs. examined letter naming tasks in which Ss had to name one of ten possible upper case letters or their lower case equivalents. Three classifications of response were possible; (1) letter identical in form and name to that immediately preceding (stimulus repetitions, SR); (2) letter with the same name but a different form from that preceding (response repetitions, RR); and (3) letter different in form and name from the preceding (non-repetitions $\bar{R}$). It was found that there was a significant advantage of SRs over RRs at both ISIs, but that this advantage was less at the longer interval. $\bar{R}$ responses were slowest and there was only a slight decrease in RT at the longer interval for both $\bar{R}$ and SR responses, so that the difference between RR and $\bar{R}$ responses increased. Eichelman explained his results in terms of two processes: first, stimulus identification which depends primarily upon the visual information available from the immediately preceding stimulus. The saving in time for the SR condition due to this factor could result from the construction of some network of unit analysers which reduced the time required to "read in" the stimulus when it is physically identical to that immediately preceding. "It would be like regenerating a decaying trace or organisation of neural elements that correspond to the 'elements' making up the physical event. This might be easier than constructing a whole new organisation of neural elements, which must be done when successive forms are not visually identical." The amount of saving would be a function of the complexity of the network constructed. Hence if, for example, spatial displays are less complex as stimuli than symbolic, less of an SR effect might be expected. Eichelman suggests that where spatial displays are used, the size of the repetition effect will depend primarily on response selection processes where compatibility and strategy are important.

The second component proposed by Eichelman is the ability of the S to make the correct response. It depends upon "refractoriness of decision making processes as well as muscular and skeletal apparati used in making the response, and upon whether or not the S has prepared to make the response". It is argued that a good strategy is to be prepared to say the name of the letter just given on the previous trial, thereby decreasing RT for any response repetition. It is assumed, to explain the results, that as the ISI is increased the second component tends to decrease SR and RR RTs, while the first tends to increase SR RTs.

Thus Rabbitt (1968) explains his results in terms of stimulus classification strategies plus a motor facilitation effect, while Eichelman interprets his results in terms of a stimulus facilitation effect plus a strategy which involves preparing to execute a response. However, Rabbitt used an ISI of 20 msecs which might well preclude the possibility of much response preparation. Eichelman, on the other hand, did not investigate possible changes across trials, despite the fact that since he used 400 trials there may have been some decrease in the RR RTs similar to that found by Rabbitt for "equivalent" responses, and this trend might have continued with more trials. If this was so, Eichelman's explanation would be inadequate as the SR effect is assumed to be automatic and immediate. On the other hand, Rabbitt's explanation would be inadequate to explain the decreases found by Eichelman with increasing ISI, as the only effect according to Rabbitt's explanation should be a decrease in motor facilitation which would produce an increase, not a decrease in RT. Also, the stimulus facilitation effect in Eichelman's explanation, in which there is assumed to be a decrease in stimulus facilitation with increasing ISI for the SR reactions, is necessitated by the greater decrease in the RR when compared with the SR RTs. There is no reason why such a stimulus facilitation might not occur for identical RTs in Rabbitt's experiment. Similarly, there could be some response facilitation for the SR and RR responses in Eichelman's experiment with approximately the same decrease across ISI for both classes of response although Eichelman does attempt to argue that response factors are probably less important than stimulus factors for symbolic displays. However, since Eichelman's experiment used only one level of practice, it is possible that with more trials RR responses may have more closely approximated SR responses due to (on Rabbitt's explanation) processing strategies which would reduce the RT to the point where it can be reduced further by response facilitation.

An experiment by Entus and Bindra (1970) examined, amongst others, three situations which are relevant to the present discussion. There were two stimuli A and B. In the first situation, the _S_ was required to respond by depressing the same key to both stimuli, so that the measured response latency was a simple reaction time (SRT). In the second, the _S_ was required to respond only to stimulus A (or B) and to make no response on the occurrence of the other stimulus, so that response latency was a recognition reaction time (RRT). In the third condition, the _S_ was required to respond to stimulus A or B - whichever happened to occur on a trial - by depressing the appropriate key, so that a choice reaction time (CRT) was obtained. The ISI for the first two conditions was 2 sec., those for the third were 2 sec. and 10 sec.

A repetition effect was found for all conditions except the 10 sec. CRT situation where there was an alternation effect. The results for the SRT and RRT conditions indicated, according to Entus and Bindra, "that the effect does not depend on stimulus identification or any other complex discrimination process or on any response facilitation or inhibition processes (since a single response is specified for all responses, 'repeated' or 'nonrepeated'). Rather, the effect probably arises from sensory processing no more complex than that involved in the SRT task, perhaps from an increase in the speed of detection of repeated stimuli." The change from a repetition effect to an alternation effect in the CRT situation is attributed to the increasing difficulty of stimulus discriminability with time. Presumably some memory trace which might be assumed to decay with time, is being suggested which, with increasing ISI, would make judgements of the equivalence of repeated stimuli more difficult. While this might explain a decrease in the repetition effect, it does not explain why the repetition effect should change to an alternation effect.

An experiment emphasising the role of response effects is that of Rabbitt (1965). There were ten lights and ten keys, one key beneath each light, an ISI of 20 msecs and a stimulus sequence in which no signal ever followed itself. Each light of the left half of the display was responded to by touching the key vertically underneath with the forefinger of the left hand, similarly each light of the right half with the forefinger of the right hand. It was found that responses following responses made with the same hand were significantly faster than those following responses made with the opposite hand. Since the probability of alternations between hands was slightly greater than the probability of repetitions with the same hand, it would seem that neither the repetition of a particular signal nor of a particular response is necessary to produce a repetition effect. Merely selection of the limb with which the response is made would seem to be sufficient, indicating that in this case the repetition effect depends on the repetition of "only one of a series of decisions in the central nervous system which may collectively be called the 'program' for the selection and organisation of a response".

An experiment by Kornblum (1965), while not concerned with sequential effects, nevertheless suggests that response inhibition may also be of importance in explaining such effects. A 2-choice situation was used and the results showed that reaction was faster to the middle finger of the right hand if the other response was made with the index finger of the left hand rather than with the index finger of the right hand. This finding suggests that "a measurable proportion of the reaction time interval is consumed by processes associated with the inhibition of competing incorrect alternative responses". If it is assumed that such inhibition will take some time to dissipate, it can be seen that the repetition effect at low ISIs could be partly due to some residual inhibition affecting alternation responses. However, it would be expected that increasing the ISI would allow time for the inhibition to dissipate so producing faster alternation RTs. But the evidence reviewed in the section on the ISI suggests that the main change in RT is on repetition responses and not on alternation responses as the above explanation would predict.

Finally, an experiment by Hannes (1968), referred to previously in the section on the ISI, suggests that the complexity of the movement involved in the response might be of some importance in determining sequential effects. In a 2-choice situation a repetition effect was found with two separate keys, each pressed by the index finger of one hand, and an alternation effect when the index finger of only one hand was used to press both keys, the finger resting on a position in front of the two keys between trials. It could be suggested that, with the one finger system, e.g. Williams (1966), an alternation response is merely a continuation or repetition of the return movement to the "home" position between trials, and that a repetition response involves a movement in the opposite direction to that last made, that is, to the home position. However, as was pointed out earlier, the results are conflicting, e.g. Entus & Bindra (1970), Hale (1967).

In summary, evidence for the importance of both stimulus and response sequential effects has been found. The many-to-one S-R mapping experiments were designed to determined whether stimulus or response repetition was more important. Instead, they seemed to have changed the nature of the task thus introducing other factors which might not be important in one-to-one S-R mapping CRT tasks. Criticisms of this kind, e.g. Sanders (1970), will be dealt with in more detail in a later section concerned with procedures and analysis of sequential data.

In fact the evidence seems to support the view of Rabbitt (1968) that the S is flexible in the type of strategy he uses, and that which strategy is used will depend on the particular type of task. Thus, the origin of the repetition effect may depend upon the type of task. It was suggested in the Summary of Chapter I that increasing the difficulty of the task appears to increase the repetition effect. This can be done in a number of ways; for example, by increasing the number of S-R alternatives, decreasing the S-R compatibility or decreasing the ISI. For the increase in the number of S-R alternatives, the repetition effect may be due to stimulus processing strategies which allow the S to take advantage of any residual motor facilitation, or to bypass some central processing. The reduced compatibility may affect the central processing where repetitions of stimuli mean that the S can bypass complex central categorization processes. Decreasing the ISI may mainly affect the response system where greater motor facilitation occurs.

In fact it might be a mistake to look for a single location of the repetition effect. This view is the more plausible in that, in many cases, changes of repetition effect are due to changes in alternation RTs.

Other factors which were mentioned in the above discussion were central processing factors and preparation on the basis of subjective expectation. These two factors will be considered in the following sections.

2.2. Short-term memory

Bertelson (1963) examined two hypotheses; (a) that different mechanisms are involved in reactions to repeated and to new signals; and (b) that the same mechanisms are involved but work faster in the case of repetitions, due to some sort of facilitative aftereffect. The latter hypothesis is essentially that proposed in a previous paper (Bertelson, 1961). It was hoped to decide between these two hypotheses by examining the effect of the S-R relations on the RTs to repetitions and alternations. It was found that an incompatible S-R relationship increased the alternation RT more than the repetition. This effect was taken as inconsistent with the second hypothesis while the fact that both RTs were affected was taken as inconsistent with the first hypothesis.

In place of these two hypotheses, it was assumed that the duration of reactions to alternations depends on the S-R relationship while repetitions can be organised by a shorter process which depends on a memory trace of the preceding stimulus. The strategy adopted by the S is that of asking first whether the stimulus is identical to the immediately preceding stimulus. If not, it is assumed that in the 2-choice case the S will then check to see if it is the other stimulus. For more than two stimuli, more than these two steps will of course be required, more incompatible S-R relationships involving more classification steps than compatible ones. To explain the slight increase in the repetition effect, it is assumed that the "repeat" question is not always asked first. To explain the decrease in the repetition effect with increased ISI it is assumed that the memory trace of the preceding stimulus decays with time. This at the same time explains why the "repeat" question cannot be asked reliably on each occasion.

Hale (1967) in addition to finding a decrease in the repetition effect with increasing ISI, also found that the repetition RT decreased as the number of repetitions increased up to four in length and pointed out that Bertelson's model was inadequate to explain this. This latter effect was found at two different ISIs (100 and 600 msec), the terminal RT being different for each, again something which Bertelson's model would be unable to explain. A possible solution suggested by Hale is that perhaps the repeat question is not always asked first, but tends to be, after being reinforced repeatedly by a series of repetitions. The RT would then decrease to some limit set by the responding mechanisms when the repeat question was being asked reliably. Another difficulty for Bertelson's model not mentioned by Hale is the existence of alternation effects in 2-choice tasks at long ISIs. While the alternation effect found in his experiment with an ISI of 2 sec. was not significant, that found by Williams (1966) with between 12 and 15 sec. was significant.

Two other experiments which have challenged the memory trace hypothesis of Bertelson are those of Schvaneveldt & Chase (1969) and Keele (1969). Both experiments failed to find any decrease in the repetition effect with increasing ISI and hence no support for the memory trace hypothesis. A second experiment by Keele (1969) with interpolated activity between the end of one response and the presentation of the next stimulus (either repeating or classifying a number) was found to increase the repetition effect. On a short-term memory hypothesis, it would be expected to abolish the repetition effect.

An experiment supporting the memory hypothesis is that of Smith (1968) who found a decrease in the repetition effect as the ISI increased. However, the task was difficult insofar as Ss had to respond to either a red "1" or red "2" or green "1" or green "2", responding with the left hand if the stimulus was red, the right if it was green, and the forefinger if the stimulus number was "1" and the middle finger if it was "2".

As was pointed out in the previous section, there seems to be no reason why if tasks differ, different mechanisms should not be involved. In the above experiment the S-R mapping is complex and might well involve short-term memory to a much greater extent than easier, more compatible tasks.

Further evidence in support of the importance of memory in RT tasks is that of Landauer (1964). The task was to name which of six possible letters occurred. These letters were presented at 5 sec. intervals in a sequence in which each letter occurred equally often and at each of 11 different intervals ranging in time from 5 to 55 sec. RT for a letter was found to increase with the number of intervening letters and hence with the intervening time between it and its last occurrence. The result was interpreted as indicating that retrieval of an item from the human memory store leaves the system in a state from which the item can be recalled again in less time.

There is then some evidence to indicate that short-term memory may be important in producing sequential effects for certain RT tasks. However, the absence of a decrease in the repetition effect with increasing ISI in the experiments of Schvaneveldt & Chase (1969), and Keele (1969), and the existence of alternation effects in 2-choice tasks, suggest that other factors may be more important under certain conditions (e.g. those more compatible).

2.3. Expectancy and preparation

The explanations for the repetition effect examined so far have mostly been in terms of either some automatic facilitation of the stimulus input or response output or in terms of a strategy on the part of the S who, once he has registered that a stimulus has occurred, proceeds to classify it in a particular way. The role of the S according to these explanations is essentially passive.

The explanation to be discussed in this section emphasises the active role of the S, who is seen to prepare to respond to particular stimuli before they occur on the basis of some subjective expectation.

Bertelson's (1961) explanation of the repetition effect did not assume that Ss prepare more often for repetitions than alternations, but rather that they sometimes prepared for repetitions and sometimes for alternations, and that if they prepared for the former, with short ISIs, they were more prepared than if they prepared for the latter. This was assumed to be due to some transitory residual effect favouring repetitions.

Williams (1966) found an alternation effect and in order to test the possibility that it was due to Ss guessing more alternations that repetitions, they were required, in one of the experiments, to predict which stimulus would occur before each trial. In another condition, Ss were required before each trial to predict which response would be required. The results showed that correct predictions led to faster RTs than incorrect, but that for correct guesses alternations were still significantly faster than repetitions. Alternations were also found to be faster than repetitions for incorrect guesses, although significantly so only for the group predicting the stimulus. Williams therefore concluded that although prediction affects RT, it is not responsible for sequence effects. It is, of course, possible that asking Ss to predict the next stimulus may not be a good measure of subjective expectancy, as it seems possible that the S could always have second thoughts about his prediction and hence alter his preparation for the next stimulus.

Hale (1967) investigated a 2-choice RT task situation using an ISI of 2 sec. In one condition Ss were merely instructed to respond to whichever signal appeared; in the other they were required to predict which stimulus would occur prior to its occurrence and their response to it. A nonsignificant alternation effect was found in the former condition and an increased alternation effect in the latter. It was also found that the prediction showed a strong negative recency or alternation tendency. These two results would seem to suggest that the alternation effect can be caused by guessing strategies, contrary to Williams' results. However, while correct predictions led to shorter RTs as was found by Williams, in this experiment the alternation effect seemed mostly to come from incorrect predictions, which does not agree with a guessing-habit explanation of the alternation effect. In addition, analysis of predictions indicated that while the percentage of predictions of a stimulus decreased as the length of the repetition sequence of that stimulus immediately preceding it increased, RTs for repetitions did not progressively increase with run length as would have been expected, but did so only for the first repetition:

subsequent repetition RTs differed little from alternation RTs. Procedural faults mentioned by Hale which might in part account for the results of these two experiments, are the use of a verbal foreperiod signal by Williams which might have provided cues as to which stimulus was to appear, and in his own experiment the use of such a highly paced task and a situation giving such a small alternation effect.

Two experiments supporting at least a partial explanation of sequential effects in terms of guessing strategies are those of Schvaneveldt & Chase (1969) and Keele (1969).

Schvaneveldt & Chase found that, with a highly compatible code, sequential effects for a 2-choice task resembled the pattern of responses in a guessing experiment. Moreover, the decreased RTs to stimuli which continued repetition or alternation sequences and increased RTs to stimuli which discontinued these sequences, was taken as implying that a set is built up before a stimulus occurs and the stimulus either does or does not fit the set. With incompatible S-R codes, this response pattern was not found and this was taken as implying that in this case Ss respond to the presented stimulus rather than prepare for it. Since a repetition effect was found in an incompatible S-R 4-choice task, it was suggested that Ss were tending to check for a repetition before retrieving the S-R code. If so, it means that Ss are capable of changing their strategy for processing the stimulus. With highly compatible codes, Ss tend to prepare for a particular stimulus event on the basis of some subjective expectancy, but as the S-R code becomes more complicated, they tend to check for a repetition first. Because no decrease in the repetition effect was found with increasing ISI, it was concluded that the type of memory involved is not affected by unfilled intervals or interpolated activity. Rather than there being a memory or motor trace of the preceding response (as assumed by Bertelson, 1963), it was regarded as a memory trace of the sequential structure of the preceding stimuli.

Keele (1969) using a 6-choice task found a clear repetition effect when the S-R relationship was incompatible, while the effect was negligible with a compatible arrangement. In a second experiment, a task of either repeating a single two digit number or classifying it into high or low, and odd or even, interpolated between each key press with the incompatible condition, was found to increase the repetition effect. In a third experiment with a 4-choice task, Ss were required to guess which signal would appear prior to each presentation. Correctly anticipated stimuli were responded to faster than incorrectly and the effect was greater for an incompatible S-R arrangement than for a compatible. This suggests that when Ss anticipate stimuli, they also partially retrieve the corresponding response, since if anticipation had affected only stimulus identification, the decrease in RT with correct guesses should have been the same for the two S-R codes.

With the data divided into correct and incorrect guesses, there were no repetition effects. The results of the second experiment were taken as suggesting that this was not due to the intervening activity of guessing the next stimulus. Thus it was argued that the results implied that the repetition effect is due to repeated stimuli being more often anticipated or checked for than others. However, it was also found that there was in fact a slight tendency not to guess repetitions. It was argued nevertheless that when overt guessing is not required, Ss may tend to check for repetitions more frequently, so that the repetition effect could still depend on an anticipation strategy. This assumption weakens Keele's position since he has argued on the one hand that overt guessing has not interfered with the repetition effect and on the other that Ss may do something different to produce the repetition effect when overt guessing is not required. In fact his results throw some doubt on the usefulness of overt guessing as a way of determining what strategy is used when overt guessing is not required.

Hale (1969) using 2-, 4- and 8-choice tasks found a marked repetition effect for all conditions, but with both high order repetition and alternation effects, the latter being smaller than the former. He pointed out that while the results indicate a specific probability effect for the 2-choice condition, the 4- and 8-choice results indicate simply an "energising" of any alternate processing. Evidence that repeated stimuli are processed differently from alternated stimuli was provided by the fact that far fewer errors were made on repeated stimuli and that the error rate progressively decreased as the run of repeated stimuli increased. In addition, as the run length increased it was found that there was a facilitatory effect on the alternation response which terminated the run both in terms of decreased RT and decreased error rate. This was most marked in the 2-choice condition. The results were taken to indicate the simultaneous and interdependent operation of repetition and probability mechanisms. The cause of the repetition effect is not specified but is presumably assumed to be some facilitation "either involving the motor system or the latter parts of the translational activity" as suggested in his earlier paper (Hale, 1966).

Further support for at least a partial explanation of sequential effects in terms of subjective expectancy is provided by the error analysis of Kornblum (1969). He found that (1) alternation trials produce proportionally higher error rates than repetition trials, and (2) the higher the conditional probability of a repetition or an alternation, the lower the probability of an error on that type of trial. The last result could be interpreted as a decrease in the probability of an error with an increase in readiness for events of the type on which the errors occur. It was also hypothesised that the error response itself should reflect the differential state of readiness. In support of this it was found that "as readiness for the more probable event increases, be it a repetition or nonrepetition, not only does the likelihood of an error on that trial decrease, but when an error does occur, then the error response is of the type for which readiness is greatest".

An explanation of sequential effects in terms of expectation and preparation is capable of explaining the effects of different probabilities of repetitions and alternations in a sequence, e.g. Bertelson (1961), and Moss, Engel & Faberman (1967).

However, that an explanation in these terms alone is inadequate seems to be indicated by the fact that generally for 2-choice tasks with equal numbers of repetitions and alternations, repetition effects have been found with low ISIs while alternation effects have been found with long ISIs. However, the latter effects can be explained in terms of expectancy and preparation by the gamblers fallacy phenomenon where Ss tend in a random sequence to predict more alternations than occur by chance (for example, Jarvik, 1946). If this was the case, repetition effects at low ISIs would then require some other explanation, perhaps in terms of some facilitation effect of the previous response as has been suggested by Hale (1967) although this may not be entirely independent of probability effects, as pointed out by Hale (1969).

Some of the characteristic tendencies of Ss in responding sequentially in multiple choice tasks (k greater than 2 where k is the number of S-R alternatives) have been summarised by Rabinowitz (1970). These include the tendency to (1) not repeat responses, (2) respond to adjacent loci on successive trials (that is respond in a series), and (3) use all k possible responses on k successive trials.

It was also noted that the tendency not to repeat responses decreases as a function of increasing inter-response interval.

However, as was pointed out in connection with Keele's (1969) experiment, overt guessing tasks may not provide the best clues to an understanding of sequential effects in choice RT situations. In fact the tendency not to repeat responses reported by Rabinowitz would seem to preclude any explanation of the repetition effect in these terms for multiple choice situations. Only in the 2-choice situation where ISIs are relatively long (long enough perhaps to allow prediction of the next stimulus) would a guessing strategy in the form of the gamblers fallacy seem to be an adequate explanation of the sequential effects.

Remington (1969) using a 2-choice task and an ISI of 4 sec. found higher order repetition effects such that the RT decreased as the length of a run of repetitions increased, and increased as the length of a run of repetitions immediately preceding an alternation increased.

These effects would seem to be most easily explained in terms of the kind of expectation and preparation suggested by Schvaneveldt & Chase (1969) except that, as pointed out in a previous section, the finding of a repetition effect with an ISI of 4 sec. is anomalous and could not be due to the gamblers fallacy phenomenon. In a later paper Remington (1971), found higher order repetition effects for a 4-choice task, again suggesting the operation of subjective expectancy and preparation.

The role of subjective expectancy in explaining choice

RT has been supported by a number of studies not concerned with sequential effects, e.g. Bernstein & Reese (1965); Hinrichs (1970); Hinrichs & Craft (1971a). In these experiments the effects of variables such as stimulus uncertainty and probability of stimulus occurrence on the RTs to correctly and incorrectly predicted stimuli were examined. However, Hinrichs & Craft point out that they obtained ambiguous results in a comparison between the same condition requiring and not requiring prediction, and point out that "the validity of interpreting the probability effect in experiments where verbal predictions are not required on the basis of results where predictions are made, must remain an open question".

In a further experiment by Hinrichs & Krainz (1970) Ss had to predict which of three stimuli would occur when two stimuli were mapped onto one response and the remaining stimulus onto a second response. The results indicated that Ss' expectancy is primarily a set to perceive a particular stimulus rather than to execute a particular response. These results are consistent with those of Hawkins, Thomas & Drury (1970), Orenstein (1970) and Hinrichs & Craft (1971b) who used similar S-R paradigms and concluded that generally perceptual bias occurs; response bias only occurs when response difficulty is increased due to an increase in the number of responses, reduced S-R compatibility, reducing the ISI or increasing response frequency differences.

Further evidence in support of an expectancy hypothesis comes from an experiment by Geller & Pitz (1970) using a 2-stimuli 2-responses paradigm and a 3-stimuli 2-responses paradigm, where two of the stimuli were paired with one response, and the remaining stimulus with the second response. Choice RT was again found to be faster to predicted than non-predicted events. With effects of prediction controlled, choice RT was little influenced by variables such as confidence level, run length, or probability of the stimulus in the 2-choice task. However, the latter two variables did have markedly significant effects in the 3-stimuli 2-responses design. Higher order repetition effects were found for both predicted and non-predicted stimuli so that these could not be due to whatever expectancy is reflected in the S's predictions. It was pointed out that this result was not at variance with that of Keele (1969) who found no repetition effect when Ss' predictions were taken into account, since Keele only examined first order and not higher order effects.

Geller et al (1971) found that in a 2-choice task, prediction outcome, stimulus probability and stimulus run length independently influenced RT. This was taken as support for an expectancy hypothesis insofar as changes in these independent variables, which might be assumed to reflect an increase in expectancy, were accompanied by a decrease in RT. An implication of this is that prediction alone does not reflect the total expectancy occurring in this situation.

In an experiment using an extension of the prediction method which is of more relevance to sequential effects, Whitman & Geller (1971a) analysed the effects of past predictions on RTs to present predictions, and found further support for an expectancy hypothesis, since RT decreased to a correct prediction as the number of preceding correct predictions increased, and increased to a correct prediction as the number of preceding incorrect predictions increased. This result was taken as support for a continuous rather than a dichotomous theory of expectancy. The theory that expectancy is continuous (for example, Geller & Pitz, 1970) assumes that the S's readiness for a given stimulus may vary in degree, whereas the theory that expectancy is dichotomous (for example, Falmage, 1965) assumes that the S is either "set" or "unset" for any given stimulus. If expectancy is a continuous process, the above results could be explained by assuming that "a run of correct prediction outcomes increased the S's degree of expectancy for the next predicted stimulus, which in turn augmented the response facilitation to identify a correctly predicted stimulus. On the other hand, a run of incorrect prediction outcomes reduced the S's degree of expectancy for the stimulus predicted and thus decreased the facilitation to identify a correctly predicted stimulus". There seems to be some uncertainty in this statement as to whether expectancy affects mainly preparation for the stimulus or the response. However, it was also found that although the RTs for correctly predicted stimuli were faster than for incorrectly, the latter also decreased as the run of preceding correct predictions became longer and increased as the run of preceding incorrect predictions became longer. This latter finding was at variance with the original formulation of the expectancy hypothesis where it was assumed that an increase in the degree of expectancy would augment both the response facilitation for the predicted stimulus, and the response inhibition for the non-predicted alternative. Similarly, a decrease of expectancy was assumed to reduce both the response facilitation for the correctly predicted stimuli and the inhibition for the incorrectly predicted stimuli. It was therefore thought necessary to assume that "preceding correct predictions facilitate S's reactions to subsequent stimuli, even though the stimuli may be non-predicted; likewise, preceding incorrect prediction outcomes reduce response facilitation to non-predicted stimuli". However, some further explanation would seem to be required in order to explain why, overall, RTs to correctly predicted stimuli are faster than those to incorrectly predicted stimuli.

In a later experiment Whitman & Geller (1971b) used the same analysis of predictions with a compatible and incompatible S-R arrangement. The same results were found for the latter as for the preceding experiment but the original expectancy hypothesis was supported for the compatible arrangement except that there was no cumulative effect across runs. That is, preceding correct predictions facilitated identification of a subsequent correctly predicted stimulus and inhibited identification of an incorrectly predicted stimulus, and incorrect predictions reduced both processes. As can be seen from the change in wording, the authors now seem to take the hypothesis to refer to identification of the stimulus rather than facilitation of the response.

The above results suggested that the compatible arrangement of the previous experiment was more "incompatible" than the compatible arrangement of the latter. The results were explained by the additional assumption that, for incompatible arrangements, response selection is facilitated if a preceding prediction is correct and inhibited if it is incorrect. The fact that the response effects increase with run length indicates a cumulative effect of prediction outcomes over trials, while the lack of change in stimulus identification over runs indicates that maximum facilitation or inhibition is achieved by a single preceding prediction outcome.

The above explanations were based on evidence from previous experiments showing that correct predictions of the stimulus, rather than preparation to execute the correct response, account for the finding that faster reactions occur to predicted than to non-predicted stimuli (Hinrichs & Krainz, 1970) and that as the S-R relationship is made more incompatible, perceptual factors have less influence on choice RT, and response effects become more prominent (Schvaneveldt & Chase, 1969).

In summary, it would seem from the evidence considered that subjective expectancy does play an important part in determining choice RT and that the expectation of the stimulus is most important in RT situations where the response difficulty is minimised. This would appear to occur mostly in 2-choice discrete RT tasks. With greater than 2-choices and with incompatible S-R arrangements, however, Ss may adopt strategies which differ from their behaviour when required simply to predict which stimulus will occur next. Ss checking the preceding stimulus source before others in order to take advantage of any facilitation of the repeated response or circumvention of central processing, would seem to be an example of this. In the 2-choice case, where the ISI is low, response factors would seem to be more important and would seem to be due largely to some automatic response facilitation rather than espectancy.

2.4. Summary and review of the explanations of sequential effects

It seems appropriate at this stage to review briefly the explanations that have been put forward for sequential effects.

Most explanations of sequential effects have incorporated the notion of subjective expectancy. An exception is the model of Williams (1966) which attempts to explain an overall alternation effect in terms of a comparison system which matches each new input against the input received on the previous trial. A match (that is, a repetition) decision is assumed to take longer than a non-match decision (that is, an alternation). The repetition effect found at lower ISIs in other experiments is attributed to the properties of a response system which has not come fully to rest between trials. However, this model would be incapable of explaining higher order alternation effects of the kind found by Schvaneveldt & Chase (1969) if these were found to accompany a first order alternation effect as found by Williams.

Schvaneveldt & Chase (1969) have attempted to explain sequential effects in 2- and 4-choice situations, in terms of subjective expectancy and preparation only. However, this explanation assumes that, as they found in their experiment, there is no overall decrease in the repetition effect with increasing ISI as was found by Bertelson (1961), Bertelson & Renkin (1966) and Hale (1967). For decreasingly compatible S-R arrangements, Schvaneveldt & Chase have attempted to explain the sequential effects in terms of a shift in the mode of processing, assuming that checking for a repetition before retrieving the S-R code may be an efficient strategy as the code becomes more complex.

Bertelson (1961) also argued for an explanation in terms of subjective expectancy but with preparation for repetitions being faster than that for alternations at low ISIs due to some facilitative aftereffect of the repetition response. In a later paper, (Bertelson, 1963), he proposed another explanation in terms of processing strategies, by which the S was assumed to check first on most occasions for a repetition, on the basis of a memory trace of the preceding response which was assumed to decay with time, thus explaining a decrease in the repetition effect with increasing ISI. However, Remington (1969) criticised this explanation as being unable to explain the higher order repetition effects found in his experiment.

A mathematical model incorporating the notion of subjective expectancy plus preparation is that of Falmagne (1965). However, "preparation" in Falmagne's model unlike that in Bertelson's, is not assumed to involve a process in real time which might be affected by a facilitative after-effect.

Laming (1969) has also attempted an explanation primarily in terms of subjective expectancy, but without Bertelson's additional notion of preparation and a facilitative aftereffect. He has argued that the change in sequential effects may be explicable in terms of subjective expectancy, plus an assumption that the S may process the signal series differently depending on how much time is available to do so.

Another explanation similar to that of Bertelson's (1961) involving both subjective expectancy and some physiological changes, is that of Krinchik (1969) who hypothesises two mechanisms, "one of these mechanisms (which we will call 'physiological') changes the level of the physiological reactivity of the sensory motor system with regard to the objectively given regime of presenting signals owing to sensitization and facilitation". This mechanism, he suggests, contributes to the repetition effect. "The second mechanism (which we will call 'psychological') changes the level of readiness of the subject for the perception of the signal and the reaction to it (and, consequently, changes the level of the sensorimotor system reactivity) under the influence of subjective estimation of the moment at which a given signal will occur". A similar model is that of Hannes (1971) who also proposes two mechanisms, one of which is also a mechanism depending on subjective probability. However, while Krinchik's other mechanism is "physiological" and affects the sensorimotor system, that of Hannes appears to be more central in origin, involving the processing of incoming information, but still depending on subjective probability.

2.5. Sequential data Procedures and analyses

Initially the analysis of sequential data only extended to the effect of the immediately preceding response. With this analysis the effect of such variables as number of S-R alternatives, ISI, S-R compatibility and the proportions of repetitions and alternations in sequences were examined.

The most common procedure used to determine the role of the stimulus and response processes in sequential effects, has been the information reduction paradigm when more than one stimulus is mapped onto one response. Generally this procedure has helped to determine the conditions under which stimulus and response processes are involved, as the evidence suggests that both are important, depending on the experimental situation. However, there are some criticisms that have been made of the procedure. The first, mentioned by Bertelson & Tisseyre (1966), suggested that the perceptual similarity may cause stimulus generalisation so that "the analysis of the stimuli could presumably be reduced to the time necessary for the detection of the common element, and results suggestive of a response effect might be produced".

Sanders (1970) suggests that "more dissimilar signals are likely to produce mutual associative inhibition or a negative transfer effect". Since for the two signals mapped onto a response with unequal probability, the signal with high probability will have its connection reinforced in the majority of responses, and the signal with low probability will suffer most from inhibition, artificial results in the direction of a perceptual bias would be produced. Hence, rather than measuring differences in speed of identification or response, the paradigm may measure the degree of S-R interference. Sanders in the above mentioned article found some evidence in support of this argument.

The second procedure used to investigate the role of subjective expectancy in choice RT is that of asking the Ss to predict the next stimulus and their response to it. As has been mentioned, the results support an explanation in terms of subjective expectancy, but most have found that an explanation solely in these terms is not adequate and some other mechanism is required in some circumstances. The results have also tended to indicate that the S's prediction may not be an accurate guide to his method of processing the information (e.g. Keele, 1969) and may not account for all the effects of subjective expectancy (e.g. Geller, et al, 1971).

Perhaps the most important tool in revealing sequential effects and their possible causes has been the higher order sequential analysis in which the effects of stimuli more than one back in the sequence have been investigated. The most complete analysis of this kind has been that of Remington (1969, 1971) for both 2-choice and 4-choice tasks.

The results of higher order analyses have shown the model of Bertelson (1963) for the repetition effect to be inadequate, and suggested that there may be higher order alternation effects (Schvaneveldt & Chase, 1969) accompanying a first order alternation effect, in which case Williams (1966) model for the alternation effect is also inadequate. The findings of the higher order analyses have also provided strong support for explanations in terms of subjective expectancy and preparation. Both Remington (1969) for repetitions and Schvaneveldt & Chase (1969) for both repetitions and alternations found symmetrical higher order effects, that is, RT decreased as a sequence became longer, and increased with the length of the sequence immediately prior to its discontinuation. This result is compatible with the sort of expectancy theory proposed by Geller & Pitz (1970) where it is assumed that what is gained in RT to a prepared stimulus, is lost in the RT to an unprepared. It also tends to support a continuous theory of expectancy where the S is assumed to be capable of increasing or decreasing preparation for a particular stimulus, so that the more prepared he is for a particular stimulus, the shorter his RT will be, and the longer it will be if the unexpected stimulus occurs.

In view of the above, it seemed that a fruitful approach to the further study of sequential effects might lie in using the higher order analysis proposed by Remington for 2-choice tasks in a parametric study of changes in sequential effects across ISIs, and in a comparison of compatible with incompatible S-R arrangements.

The further parametric study of ISIs would seem to be required insofar as there still seems to be some uncertainty as to whether the repetition effect decreases with ISI and whether it changes at some point to an alternation effect. In terms of the explanations put forward for the repetition effect, the results of such a study would have implications for the role of short-term memory and also for the adequacy of an explanation solely in terms of subjective expectancy. If such an explanation were adequate, one might expect the higher order effects to be of a similar kind at all ISIs. If, on the other hand, a second mechanism were required, for example some motor facilitation, one might expect the higher order effects to be different at short ISIs. In particular, at short ISIs, while a facilitative aftereffect might be expected to reduce RT progressively as the length of a repetition sequence increased, it would not be expected to have any corresponding effect on an alternation response.

Also, the success of the higher order analysis with 2-choice tasks suggests that a more detailed analysis of greater than 2-choice tasks would be instructive.

CHAPTER III.

DATA ANALYSIS, APPARATUS, STIMULUS SEQUENCES AND PROCEDURE FOR THE TWO CHOICE EXPERIMENTS

3.1. Higher order sequential analysis

As was noted in Chapter II, the repetition effect by Bertelson (1963) and the alternation effect by Williams (1966) have both been assumed to be due primarily to the immediately preceding event. However, Remington (1969) has shown that for the repetition effect at least, events two, three and four back in the series can also contribute to the difference between repetitions and alternations, and has argued that these must therefore be taken into account in formulating any explanatory model. A major aim of the following experiments is then to apply Remington's type of ananlysis in order to see whether higher order sequences also need to be taken into account in any explanation of the alternation effect.

Briefly, Remington's analysis consists of separating out all the possible combinations of the two stimulus events in sequences of up to five in length. Thus the first order RT, which may be represented by A, is the overall mean RT. The second order consists of two RTs, that for the case when a stimulus is preceded by the same stimulus (AA), and that for the case in which it is preceded by a different stimulus (BA). Similarly, there are four third order RTs corresponding to the four possible combinations, AAA, ABA, BBA, and BAA; eight fourth order RTs; and sixteen fifth order.

From the total thirty sequential responses, it is possible to separate out those for <u>repetition</u> sequences of different lengths, that is AA, AAA, AAAA, and AAAAA; and those for sequences which discontinue repetition sequences of different lengths, that is, BA, BBA, BBBA and BBBBA.

Similarly, it is possible to separate out responses for <u>alternation</u> sequences of different lengths, that is, BA, ABA, BABA and ABABA and those which discontinue alternation sequences of different lengths, that is, AA, BAA, ABAA and BABAA.

3.2. <u>Statistical analysis</u>

In order to test the significance of any possible higher order repetition effects, analyses of variance were performed in which the raw scores were (a) the differences between the RTs of repetition sequences of different lengths, that is, AAA-AA, AAAA-AAA, and AAAAA-AAAA, and (b) the differences between the RTs of the discontinuations of repetition sequences of different lengths, that is, BBA-BA, BBBA-BBA and BBBBA-BBA. Another factor in the analysis was a comparison between (a) and (b).

In the summary tables of these analyses, which are shown in the Appendix, the above factors are labelled "differences between sequence lengths" and "difference between the differences" respectively.

In order to test the higher order alternation effects the same analyses of variance as those used for the higher order repetition effects were performed except that the differences between alternation sequences of different lengths and the differences between the discontinuations of alternation sequences of different lengths were used as the raw scores, that is, ABA-BA, BABA-ABA, ABABA-BABA and BAA-AA, ABAA-BAA, BABAA-ABAA. Again another factor was a comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences.

In both higher order analyses, "Ss" was an additional factor. Other factors, such as number of trials, ISI etc. varied from one analysis to another. Since the higher order analyses were used on the data of all the 2-choice experiments, they will be referred to for convenience simply as "higher order repetition analysis" and "higher order alternation analysis".

The full tables for these and all other statistical analyses are given in the appendix along with significance levels. Any effect referred to as significant in the text will indicate a level of at least $p < .05$.

3.3. Apparatus

The apparatus was the same for all the 2-choice experiments. Stimuli were presented by means of two lights of 6 mm diameter set with centres 12 mm apart and mounted on a black board with a white vertical line between them. The board was situated 2.8 metres from the S. Responses were made with two flat-topped telegraph keys mounted on a table in front of the S. The left index finger operated the left hand key in response to the left light and the right index finger the right hand key for the right light. A pressure of 140 gms was required to operate the keys. RT was recorded in milleseconds from the onset of the stimulus to the depression of either of the keys. Recording equipment was situated in a room adjacent to that in which the experiment was conducted. Stimuli were presented and responses recorded by means of computer-programmed paper tapes.

3.4. Stimulus sequences

Six different runs of one hundred trials each were prepared from random number tables with constraints ensuring that both stimulus lights were presented equally often and that at least two examples of each possible sequence of five stimuli occurred in each run.

3.5. Procedure

Each session of each experiment consisted of several runs with a rest period of approximately two minutes between each. Ss were informed of the number of runs and the ISI before each session. They were then told that both the stimuli would be presented randomly an equal number of times in each one hundred trials, and were instructed to respond as rapidly as possible while keeping their error rate down to less than five percent.

CHAPTER IV.

A HIGHER ORDER ANALYSIS OF TWO CHOICE SEQUENTIAL EFFECTS ACROSS INTER-STIMULUS INTERVALS

In view of the conflicting evidence presented in Chapter I as to whether sequential effects change with increasing ISI, it was decided in the first two experiments to conduct, using 2- choice RT tasks, parametric studies examining sequential effects across ISIs.

4.1. Experiment 1.

At the time of carrying out the first experiment, the apparatus used allowed a minimum ISI of 2 sec., so that intervals of 2, 4 and 8 sec. were chosen. The literature indicates that alternation rather than repetition effects are likely to occur at these intervals, and they were in fact found in this experiment.

Since it was suggested in Chapter I that a partial explanation for Schvaneveldt & Chase's failure to find a change in the sequential effects with increasing ISI might be the low number of trials given, 600 trials were used.

METHOD

Subjects. The Ss were five male and one female volunteers who were naive as to the aims of the experiment and ranged in age from 20 to 40 years.

Procedure. Each S was assigned to one of the six possible orders of the three ISIs and attended on three consecutive days, completing the six different runs of stimuli at a different ISI on each day. Thus the 8 sec.

interval session lasted for approximately one and a half hours, the 4 sec. for one hour and the 2 sec. for half an hour.

RESULTS

Initial inspection of the results indicated that those of the first one or two runs differed from those of later runs. Accordingly, the first two and the final four runs of each ISI condition were combined and the mean RTs calculated for each possible combination of stimuli up to and including the fifth order. The lowest number of responses upon which a fifth order mean was based for the first two runs combined was twenty-five, most being calculated from approximately thirty responses. Lower order mean RTs were, of course, based upon substantially larger numbers of responses. The means for the last four runs combined were based upon approximately twice as many responses as for the first two runs. These results are set out graphically in the form of tree diagrams in figure 4.1 where each node represents the mean RT for a particular combination of stimulus events. The single letter A represents the overall mean RT. AA and BA indicate the RTs for a stimulus preceded by the same and different stimuli respectively, and similarly for the third, fourth and fifth order sequences. Errors amounted to approximately 2% of the total number of responses, and were included in the analyses as if they had been responses to correct stimuli.

The results shown in figure 4.1 reveal both second and higher order sequential effects giving faster <u>alternations</u>

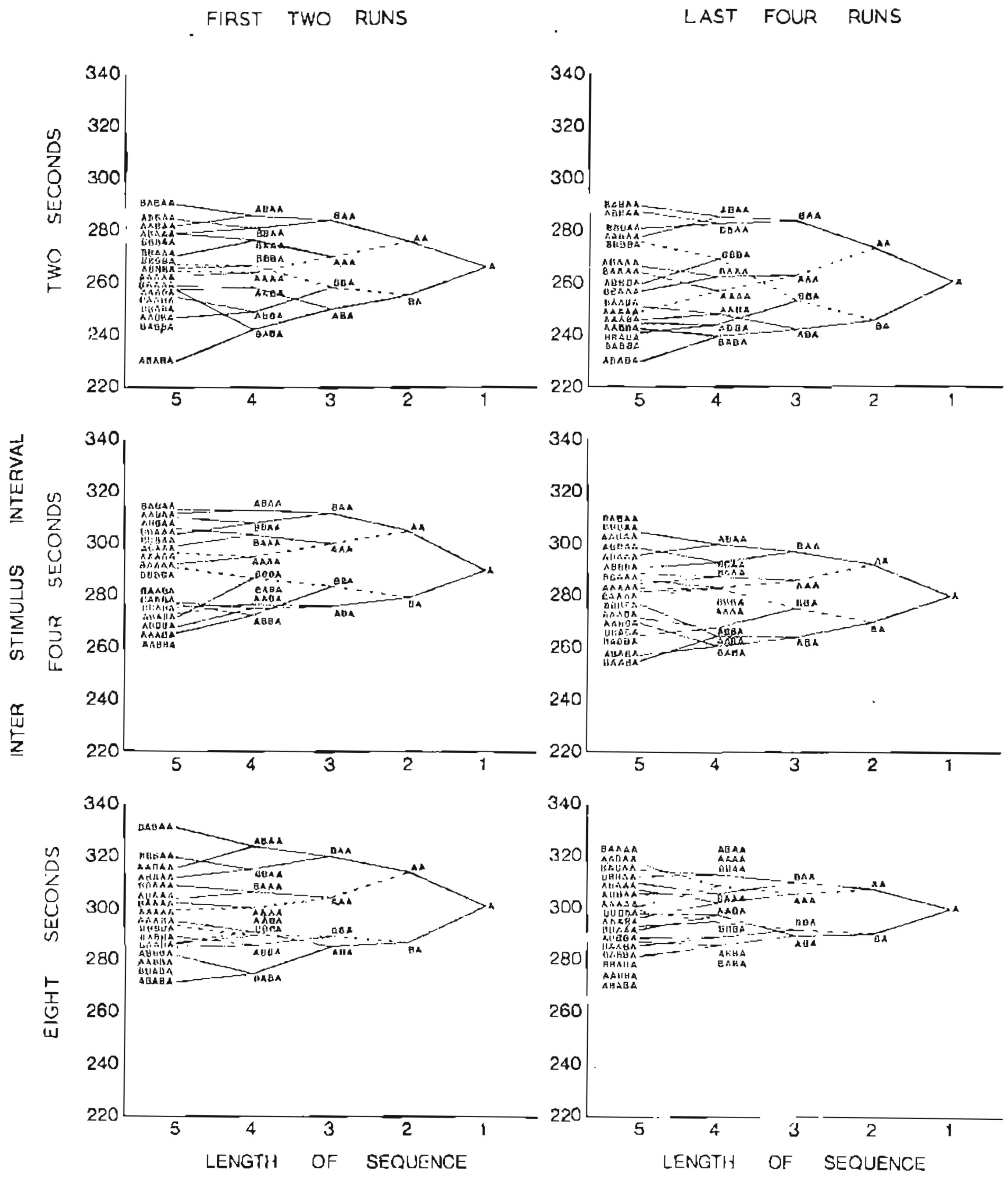

Fig. 4.1. Tree diagram analysis with RT in milleseconds for each interstimulus interval and for the first two and last four runs.

than repetitions. The effects are of a similar pattern to those found by Remington (1969) except that in his experiment repetitions were faster than alternations. RTs decrease as the length of an alternation sequence increases, that is, from BA to ABA to BABA to ABABA. Similarly, for the upper branch of the tree diagrams it can be seen that a stimulus which does not continue the alternation sequence is responded to relatively slowly, and that this slowness generally increases with the length of the preceding alternation sequence, that is, from AA to BAA to ABAA to BABAA.

A three-way analysis of variance was performed on the differences between AA and BA across the three ISI conditions and over runs (ISI x number of runs x Ss). There was no significant effect due to ISI but there was a significant effect due to number of runs. From the diagrams, this decrease from the first 2 to the last 4 runs does not appear to be very marked except in the 8 sec. condition. However, there was no significant interaction between ISI and the number of runs.

In the higher order alternation analysis, with other factors being first 2 vs. last 4 runs and ISI, the only significant main effect was that due to the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences. The only significant interaction was that due to the significant main effect x ISI. These results indicate that higher order alternation effects do occur and that they decrease with increasing ISI. From the diagrams, this decrease appears to be confined to the last 4 runs. However, the interaction corresponding to this was not found to be significant.

Sequences of <u>repetitions</u> and the discontinuations of such sequences are shown by the dashed lines in the diagrams. It can be seen that generally, the RT decreases as the length of the repetition sequence increases and that the opposite occurs with increasing length of repetition sequence preceding a discontinuation.

In the higher order <u>repetition</u> analysis, again with other factors being first 2 vs. last 4 runs and ISI, the only significant effect was that due to the comparison between differences involving repetition sequences and those involving the discontinuations of repetition sequences.

DISCUSSION

Williams' model for the alternation effect assumes a comparison system which matches each new input against the input on the previous trial. Comparisons resulting in a "match" decision are assumed to require more time than comparisons resulting in a "nonmatch" decision. It is clear from the present results, however, that this model is inadequate insofar as it assumes that only the immediately preceding stimulus is important. Remington (1969) dismissed Bertelson's 1963 model for the repetition effect for the same reason. A parsimonious explanation for both the present results and those of Remington for repetitions can be offered in terms of flesible guessing strategies as suggested by Keele (1969) and by Schvaneveldt & Chase (1969), perhaps involving some kind of preparation which can be increased according to the number of previously correct anticipations. Thus, the longer the preceding sequence of either repetitions or alternations, the shorter would be the RTs for stimuli which continued the sequence, and the longer would be the RTs for stimuli which discontinued it. There might perhaps be a limit after which the S would begin to expect a change from the repetition or alternation sequence, but this was not apparent for sequences of up to five in length in the present results for the alternation effect, nor in Remington's for the repetition effect.

The alternation effects in the present experiment could be explained by assuming that Ss tended to begin with an initial bias in favour of more alternations than repetitions, perhaps analogous to the gambler's fallacy phenomenon.

The fact that, overall, the RTs for repetition sequences decrease as the length of the sequence increases and that the opposite occurs for the discontinuations of such sequences could be explained by further assuming that Ss on some occasions are prepared to change their strategy from preparation for alternations to preparation for repetitions after the first two or three of a run of the same stimulus, reverting back, however, to the alternation strategy after the occurrence of the next alternation.

The overall decrease from the first 2 to the last 4 runs in the second order alternation effect might perhaps be due in part to the S changing his strategy towards more preparation for repetitions, perhaps as a result of becoming more aware that there are equal numbers of repetitions and alternations. The slight increase in the higher order repetition effects across runs in the 2 sec. condition would be consistent with this. In the 8 sec. condition, the decrease in the second order alternation effect and the apparent decrease (albeit non-significant) in the higher order alternation effects from the first 2 to the last 4 runs might have been due to boredom, causing Ss to make less thorough preparation for their reactions. Ss did report that they found the one and a half hours in the 8 sec. condition extremely tiring.

A decrease in the S's preparation due to boredom might also account in part for the overall decrease in the higher order alternation effects with increasing ISI. However, this result might also be expected on the above explanation insofar as stimuli further back in the sequence would be likely to have less effect the further removed in time they are from the present stimulus, since the S's expectation and preparation are presumably based on memory traces of the preceding stimuli which might be assumed to decay with time. On this explanation, one might also expect that the higher order repetition effects would decrease with increasing ISI. While there is some suggestion from the diagrams that this is so, the effect was not found to be significant, perhaps because the repetition effects are not as marked in any of the conditions as the alternation effects.

Remington obtained a repetition effect with a 4 sec. ISI while the present experiment found alternation effects for 2, 4 and 8 sec. ISIs. Since there appears to be no obvious difference in the procedures used that might account for this difference, this result suggests that the repetition and alternation effects are not definitely confined to a particular range of ISIs. If so, this fact would appear to lend further support to an explanation of alternation and repetition effects in terms of flexible strategies which the S may vary according to circumstances. However, the factors influencing such strategies are not at present clear and obviously require further investigation.

4.2. Experiment 2.

In this experiment, the same higher order analysis was applied to three more ISIs, this time equal to and less than 2 sec.; in fact 2000, 500 and 50 msecs. According to previous experiments reported in the literature, a first order repetition effect should be found at least at the lowest ISI. As in the previous study, 600 trials were used so that it should be possible to see whether there is any change in the repetition effect with increasing ISI. The higher order analysis should reveal any changes in higher order sequential effects.

METHOD

Subjects. The Ss were 3 male and 3 female volunteers from the Psychology I course at the University of Adelaide who were naive as to the aims of the experiment. They ranged in age from 17 to 25 years.

Procedure. This was the same as that used in the previous experiment except that the ISIs were 2000, 500 and 50 msecs.

RESULTS

The data for the first three and the second three runs were combined for each ISI and are presented in figure 4.2.

Errors amounted to approximately 4.5% of the data and these and all RTs less than 50 msec. were removed from the analysis.

It can be seen that for the 2000 and 500 msec. conditions, the RT to BA is faster than to AA but that for the 50 msec. condition, the reverse is the case, the RT to AA being faster than to BA. Thus there is an overall first order repetition effect for the 50 msec. condition while there are alternation effects for the 500 and 2000 msec. conditions. All Ss in the 2000 msec. condition produced alternation effects for both the first three and the last three runs. Only one S in the 500 msec. condition produced a repetition effect. This occurred in both the first three and the last three runs. Two Ss in the 50 msec. condition produced an alternation effect for the first three runs while all Ss produced repetition effects for the last three runs. There also appears to be an increase in the repetition effect for the 50 msec. condition from the first three to the second three runs. A three way analysis of variance performed on the differences between AA and BA across the three ISI conditions and across runs (ISI x number of runs x Ss) showed an overall significant effect due to ISI. No other effects were significant. Although there was no significant change across runs in the above analysis, a two way analysis of variance (ISI x Ss) performed on only the first three runs

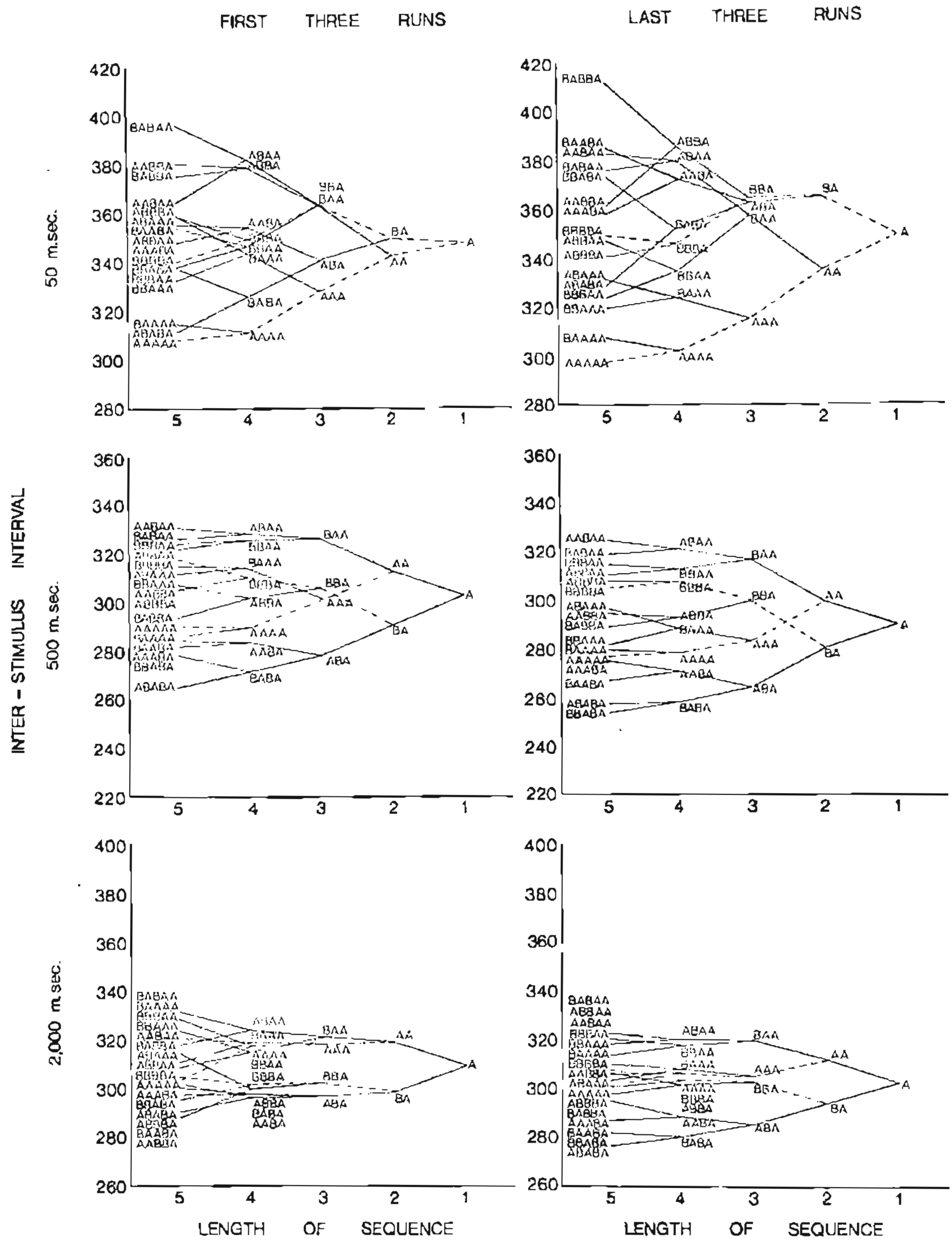

Fig. 4.2. Tree diagram analysis with RT in milleseconds for each interstimulus interval and for the first three and last three runs.

did not show a significant effect due to ISI.

Looking at the overall mean RTs, it can be seen that while those for the 500 and 2000 msec. conditions are roughly comparable, that for the 50 msec. condition is considerably higher. A three way analysis of variance comparing the overall mean RTs across the three ISIs and across runs (ISI x number of runs x Ss) showed a significant difference due to ISI. No other effects were significant.

Finally, considering the higher order effects, it is clear that for all ISI conditions, the RT for alternations decreases as the length of the preceding alternation sequence increases, that is, from BA to ABA to BABA to ABABA, and that the RT for the discontinuation of an alternation sequence tends to increase as the alternation sequence prior to the discontinuation increases, that is, from AA to BAA to ABAA to BABAA. The higher order alternation effects also appear to decrease across runs in the 50 msec. condition.

In the higher order alternation analysis, with other factors being ISI and first three vs. last three runs, the only significant effect was that for the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences.

Sequences of repetitions and the discontinuations of such sequences are shown by the dashed lines in the diagram. It can be seen that generally, as the length of the repetition sequence increases the RT decreases and that this is more marked in the 50 msec. condition than in the 500 msec. condition, while there is only a slight effect in the 2000 msec.

condition. For the discontinuations of repetition sequences, while the 500 msec. condition shows a progressive increase in the RT with length of repetition sequence prior to its discontinuation, the 2000 msec. condition shows only a slight effect and the 50 msec. condition none - in fact the RT decreased from BBA to BBBA to BBBBA.

In the higher order repetition analysis, with other factors being ISI and first three vs. last three runs, there was a significant difference between repetition sequences and the discontinuation of repetition sequences. There was also a significant effect due to ISI, and a significant interaction between the length of sequence and the comparison between repetitions and the discontinuations of such sequences.

The significant difference between the differences for alternation sequences and those for the discontinuations of alternation sequences indicates that there are higher order sequential effects and, from the diagrams, these seem to be equally due to the progressive decrease in RT with increasing length of alternation sequence and the progressive increase in RT with length of alternation sequence prior to its discontinuation. The same significant difference was found for the repetition sequences, again indicating the existence of higher order effects. However, the significant effect due to ISI seems from the diagrams to be largely due to the 50 msec. condition where, as the repetition sequence increases in length, repetition RTs decrease, but RTs for the discontinuation of repetition sequences do not increase.

The significant interaction indicates that the difference between the differences for repetition sequences and those for the discontinuations of repetition sequences, depends on the length of sequence. From the diagram it would appear that most of the difference occurs between the first order and second order sequential effects, that is, between AA and AAA and BA and BBA. Differences between the second and third and third and fourth order sequential effects are less.

DISCUSSION

The fact that an analysis of variance across the first 300 trials showed no significant change in the first order sequential effects across ISIs while that for the whole 600 trials did show a significant effect indicates that the number of trials is important in obtaining this change. This could partly explain why Schvaneveldt & Chase (1969), who only used 300 trials, failed to find such a change.

It can be seen from the 500 and 2000 msec. conditions in the present experiment that effects similar to those in Experiment 1 have occurred although not to such a marked extent.

However, in the 50 msec. condition, the effects are somewhat different. There are first order and higher order repetition effects such that the longer the repetition sequence the shorter is the RT. There are also higher order alternation effects such that the longer the alternation sequence the shorter the RT, and the longer the alternation sequence immediately prior to its discontinuation, the longer the RT. But there is no corresponding increase in the RT for the longer repetition sequence immediately prior to its discontinuation, RTs in fact appearing to decrease rather than increase from BBA to BBBA to BBBBA. Thus while the higher order alternation effects in the 50 msec. condition could be explained in terms of expectation and preparation, the higher order repetition effects require a different explanation. Remington (1969) found first order and higher order repetition effects with an ISI of 4 sec. The higher order effects were similar to the higher order alternation effects found in this experiment, and could be explained by assuming that for some reason, Ss overall expected more repetitions than alternations. But the higher order repetition effects found in this experiment with an ISI of 50 msec. cannot be so explained. It appears that with the 50 msec. interval, whatever facilitation of the repetition RT occurs, it has no effect on the RT to the discontinuation of a repetition sequence.

Schvaneveldt & Chase (1969) contrasted expectancy and preparation as an explanation of the repetition effect with Bertelson's (1963) hypothesis, that Ss use a progressive classification strategy in which they begin by asking whether the present stimulus is the same as the immediately preceding stimulus. This question is asked on the basis of a memory trace of the last stimulus which is assumed to decay with time making the answer to the question less and less reliable and so explaining the decrease in the repetition effect with increasing ISI. Schvaneveldt & Chase found no significant change in the first order sequential effects across ISIs and thus no support for Bertelson's hypothesis. The present results do show a significant change across ISIs, although it does not involve a decrease in the repetition effect but rather a change from a repetition effect to an alternation effect. Hale (1967) has pointed out that Bertelson's hypothesis does not account for the progressive decrease in RT the longer the repetition sequence, nor does it account for the existence of alternation effects. Hale concluded that most evidence seemed to favour an explanation of the repetition effect in terms of some facilitation involving either the motor system or the later parts of the translational activity. It might be expected on the basis of this explanation that such a facilitation would progressively decrease the RT to repetitions as the sequence of repetitions increased in length but have little or no effect on the RT to an alternation as the length of the preceding repetition sequence increased in length. The present results would seem to support such an explanation although they do not allow a decision between the two possibilities.

If the repetition effect at low ISIs is in fact due to some motor or coding facilitation, it is perhaps surprising that this does not show itself within the first 300 trials. However, if it is still assumed that Ss expect and attempt to prepare for more alternations than repetitions, it might be expected that this would tend to disrupt the effects of facilitation. Although the effect was not found to be significant, the graphs of the 50 msec. data do suggest a decrease in the overall alternation effect across runs so that Ss might be decreasing their preparation for alternations resulting in a greater overall repetition effect. This might be due to Ss finding that at 50 msec. preparation for alternations is not an efficient strategy to adopt.

4.3. DISCUSSION OF THE FIRST TWO EXPERIMENTS

The first two experiments together have shown higher order repetition and alternation effects and a change from a first order repetition effect to an alternation effect from 50 to 2000 msec., but little change in the first order alternation effect from 2 sec. to 8 sec. In addition, the change from a repetition effect to an alternation effect would seem to depend on the number of trials given providing at least a partial explanation of the conflicting evidence concerning this change in the literature and in particular the results of Schvaneveldt & Chase (1969).

The results of both the first and higher order effects suggest an explanation in terms of guessing strategies with preparation for anticipated stimuli, whether repetition or alternation, at least for ISIs of 2 sec. and greater, with Ss overall anticipating more alternations as in the gambler's fallacy phenomenon. However, at low ISIs, the different higher order repetition effects suggest the operation of some other factor, probably in view of previous research, a motor or coding facilitation effect which favours repetition responses.

CHAPTER V.

A HIGHER ORDER ANALYSIS OF SEQUENTIAL EFFECTS IN TWO CHOICE TASKS USING COMPATIBLE AND INCOMPATIBLE S-R ARRANGEMENTS AND MASSED TRIALS

The success of the application of the higher order analysis in the previous two experiments suggests that it might be revealing to apply this form of analysis to experiments involving the manipulation of other variables. Accordingly, in the next two experiments this form of analysis was applied to 2- choice experiments involving compatible and incompatible S-R arrangements and massed trials.

5.1. Experiment 3.

Bertelson (1963), using two lights and two keys, compared a compatible S-R arrangement, that is, left key to be pressed in response to left light and right key in response to right light, with an incompatible arrangement, that is, left key in response to right light and right key in response to left light. He found that the repetition effect obtained with the incompatible arrangement was greater than that with the compatible arrangement. However, only the effect of the stimulus immediately prior to the stimulus being responded to was examined.

It is the aim of the present experiment to compare the higher order effects using a compatible S-R arrangement with those using an incompatible arrangement. Two ISIs were used, 50 msec. and 1000 msec., in order to try and obtain, using the compatible S-R arrangement, first order repetition and alternation effects respectively and to observe the effect of an incompatible arrangement on these.

METHOD

Apparatus. For the compatible S-R arrangement the left light was operated by the S's left forefinger in response to the left light and the right key by the S's right forefinger in response to the right light. For the incompatible arrangement, Ss operated the left key with the left forefinger in response to the right light, and the right key with the right forefinger in response to the left light.

Subjects. The Ss were 7 female and 5 male volunteers. They were naive as to the aims of the experiment and ranged in age from 17 to 30 years.

Procedure. Six Ss were assigned to the 50 msec. condition, the remainder to the 1000 msec. condition. Each attended for approximately half an hour on two consecutive days. On the first day, half of the Ss in each ISI condition completed the six stimulus runs, given in a random order, with the compatible S-R arrangement and on the second day completed the same six sequences with the incompatible arrangement. The other half of the Ss of each ISI group completed the same two conditions but in the reverse order.

RESULTS

The data for the six runs of each condition were combined together. They are presented in the form of graphs in figure 5.1.

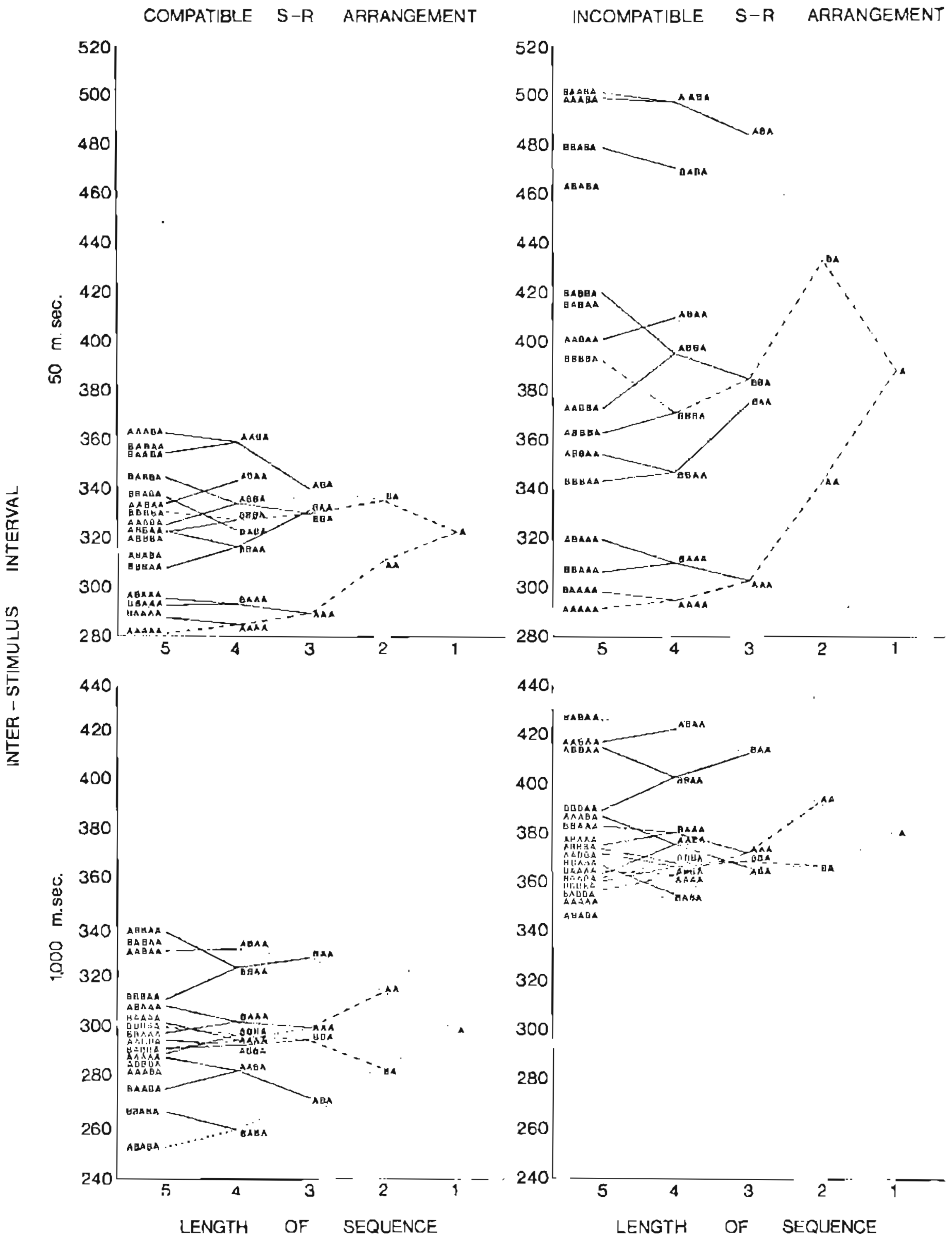

Fig. 5.1 Tree diagram analysis with RT in milleseconds for each interestimulus interval and for compatible and incompatible S-R conditions.

Errors amounted to approximately 4% of the data and these and all RTs less than 50 msec. were removed from the analysis.

Related samples t tests were used to test the significance of the differences between the differences between AA and BA between the compatible and incompatible conditions for each ISI and also between the overall mean RTs for each condition.

Comparing the overall mean RTs, it was found that there were significant increases in the mean RTs from the compatible to the incompatible conditions for both ISI conditions.

In the 50 msec. condition, it can be seen that there is an overall first order repetition effect for the compatible condition which increases in the incompatible condition. The repetition effect in the 50 msec. compatible condition was due, however, to only three Ss, the remaining three having the RTs to BA faster than those to AA. In the incompatible condition all Ss produced repetition effects and for all, the difference between AA and BA had either changed from an alternation effect to a repetition effect from the compatible to the incompatible condition or the repetition effect in the incompatible condition was greater than that in the compatible condition, the difference between the differences between AA and BA being significant.

For the 1000 msec. data, first order alternation effects were found for all Ss in both the compatible and incompatible conditions and there was no significant change in this difference between AA and BA from the compatible to the incompatible condition.

There are marked increases in RTs for both AA and BA from the compatible to the incompatible conditions with both ISIs, but for the 50 msec. the increase for BA from compatible to incompatible is much greater than that for AA. Related sample t tests showed that both increases for the 1000 msec. ISI condition were significant while for the 50 msec. condition only the increase for the BA RT was significant.

In both the higher order alternation and repetition analyses used in this experiment, the remaining factor was ISI.

<u>1000 msec. case</u>

<u>Compatible condition</u>. The only significant difference shown by the higher order <u>alternation</u> analysis was that due to the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences. From the graphs it can be seen that as the alternation sequence increases in length so the RT progressively decreases and that as the length of the alternation sequence prior to its discontinuation increases in length so the RT progressively increases.

It can be seen that there is a decrease in the RT as the length of the repetition sequence increases in length and a corresponding increase in the RT as the length of repetition sequence immediately prior to its discontinuation increases. The higher order <u>repetition</u> analysis indicates a significant effect due to the comparison of differences involving repetition sequences and those involving the discontinuation of repetition sequences. The trend is most marked for the differences between AA and AAA and between BA and BBA. In line with this was the significant interaction between length of sequence and the comparison involving the differences between repetition sequences of different lengths and those involving the discontinuations of repetition sequences of different lengths. There were no other significant effects.

Incompatible condition. It can be seen that generally, the RT decreases as the length of the preceding alternation sequence increases and that the RT increases as the length of the alternation sequence immediately prior to its discontinuation increases. The only exception is the lack of a decrease in RT from BA to ABA. The same analysis of variance as that used for the compatible condition showed a significant effect due to the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences. The only other significant effect was that due to length of sequence.

There appears to be a progressive decrease in the RT as the repetition sequence increases in length but there is little change in the RT for the discontinuations of repetition sequences as the length of sequence prior to the discontinuation increases. However, the higher order repetition analysis showed no significant effects.

50 msec. case

Compatible condition. It can be seen that there are higher order alternation effects in that the RT decreases as the length of alternation sequence increases (with the exception of the difference between BA and ABA) and that the RT increases as the length of the alternation sequence prior to its discontinuation increases. This is supported by the higher order alternation analysis where the only significant effect is that due to the comparison between the differences involving alternation sequences of different lengths and those involving the discontinuations of alternation sequences of different lengths.

For the higher order repetition effects, it can be seen that as the repetition sequence increases in length, so the RT decreases, but that there is little change in the RT for the discontinuations of repetition sequences of different lengths as the length of the repetition sequence immediately prior to the discontinuation increases. However, the higher order repetition analysis showed no significant effects.

Incompatible condition. It can be seen from the graphs that the differences between RTs for the various sequences have increased markedly when compared with the compatible condition. For the higher order repetition sequences, there appears to be a greater relative decrease in RT as the repetition sequence increases in length from AA to AAA, but little change in the differences between AAA and AAAA and AAAA and AAAAA. There is certainly no increase in the RT for the discontinuation of repetition sequences as the length of the repetition sequence immediately prior to it increases. In fact there is a marked decrease from BA to BBA and little difference between BBA, BBBA and BBBBA. This is supported by the higher order <u>repetition</u> analysis where the only significant effect is that for the length of sequence.

Similarly, for the higher order alternation sequences, the differences for the second order sequential effects are in the same direction and are greater than those for the third and fourth orders. Again the higher order <u>alternation</u> analysis shows a significant effect due to length of sequence. However, there is also a significant interaction between length of sequence and the comparison between the differences for alternation sequences and those for the discontinuations of alternation sequences. This would appear to be due to the fact that only for the third and fourth order sequential effects do RTs both decrease as the alternation sequence increases in length and increase as the alternation sequence immediately prior to its discontinuation increases in length. More important than this, however, is the fact that instead of the fourth and fifth order RTs for the discontinuations of alternation sequences being greater than those for the alternation sequences as in the compatible condition, they are considerably less.

DISCUSSION

The sequential effects found for the compatible S-R arrangements for both the 50 msec. and 1000 msec. ISIs are similar to those found in the two previous experiments. An explanation of these effects was offered in terms both of strategies by which the S is assumed to prepare for certain stimuli, either repetition or alternation, on the basis of some expectation, and also in terms of a coding or motor facilitation for the repetition response at low ISIs.

Bertelson (1963) found that RTs to new signals were more affected by an incompatible arrangement than were those to repeated signals. Using an ISI of 50 msec. he found that the repetition effect was increased from the compatible to the incompatible arrangement. Similar results were obtained in this experiment using the same ISI. However, Bertelson's explanation in terms of a decaying memory trace does not explain the progressive decrease in RT as the length of the repetition sequence increases, nor does the proposed classification strategy account for the presence of higher order alternation effects at low ISIs or first order alternation effects at higher ISIs as found in this experiment with an ISI of 1000 msec. and in the two previous experiments.

If an explanation in terms of both preparation and facilitation is correct, it might be expected that an incompatible arrangement would increase the difficulty of preparation due to the increased complexity of the S-R code but would have little effect on a motor or coding facilitation.

In the 1000 msec. incompatible condition there should be an increase in both repetition and alternation RTs due to the more complex code but this should be larger for the alternations since repetitions could presumably benefit on some occasions from bypassing the code. There does seem to be some facilitation, though not significant, of the higher order repetition RTs and since there is little change in the RTs for discontinuations of repetition sequences as the repetition sequence prior to the discontinuation increases in length, the facilitation would seem to be similar to that found in the 50 msec. condition and not due to some change in the strategy of the S. Hence there would still appear to be some repetition facilitation even after 1000 msec., most probably not a motor facilitation which may well have disappeared after 1000 msec. but more likely due to a saving in coding time.

It is evident from the analyses and diagrams that the increase in the alternation RT is approximately the same as that for the repetition RT and not greater as might have been predicted. But the presence of higher order alternation effects suggests that unlike in the 50 msec. condition, Ss are still capable within 1000 msec. of some preparation for the next stimulus which presumably would involve not only directing attention to the appropriate stimulus but also at least a partial retrieval of the corresponding response (e.g. Keele, 1969). In fact it would seem to occur to such an extent as to match whatever savings occur for the repetition response, resulting in no change in the difference between AA and BA from the compatible to the incompatible arrangement.

In the 50 msec. incompatible condition one might again expect less preparation while a motor or coding facilitation would remain unaffected. The results are consistent with this explanation insofar as the higher order alternation effects present in the compatible condition are no longer present to the same extent in the incompatible condition, while the higher order repetition effects are still evident. The fact that there is little change between the compatible and incompatible conditions for repetition RTs following long sequences of repetitions suggests that there is a much greater saving in coding time for the 50 msec. than the 1000 msec. ISI.

All RTs in the incompatible conditions might be expected to be increased over their compatible equivalents due to the Ss spending more time checking that the response to the stimulus is the correct one. This might be assumed to take much longer for alternations than repetitions. While an ISI of 1000 msec. could provide adequate time in which to do this, 50 msec. might not so that checking of alternations would interfere with and hence delay subsequent responses (e.g. Welford, 1959). This would explain the much greater spread of RTs in the 50 msec. when compared with the 1000 msec. incompatible condition if it is further assumed that greatest interference is on the immediately following response with diminishing effect on subsequent responses.

5.2. Experiment 4.

Most experiments concerned with sequential effects in serial RT tasks have usually presented the trials in blocks of not more than 300 trials, giving the S a rest period of several minutes between blocks.

The aim of the present experiment is to examine the effect of presenting to the S a single block of 600 trials without rest periods between any of the trials.

In an attempt to examine the effects on both repetition and alternation effects, two ISIs were used, one below one sec., the other above one sec.

METHOD

Subjects. The Ss were 4 male and 2 female volunteers from the Psychology I course at the University of Adelaide. They were naive as to the aims of the experiment and ranged in age from 17 to 20 years.

Stimulus sequences. Two different runs of six hundred trials each were prepared from random number tables with constraints ensuring that both stimulus lights were presented equally often and that at least six examples of each possible sequence of five stimuli occurred in each run. The ISIs were 2000 msec. and 1 msec.

Procedure. Each S was assigned to one of the two possible orders of the two ISIs and attended on two consecutive days, completing the 600 trials at a different ISI on each day. Ss were told the 600 trials were to be completed without any rest period between them.

RESULTS

The data for the first, second and third 200 trials were combined separately across Ss for each of the ISI conditions. The results are presented in the form of graphs shown in figure 5.2.

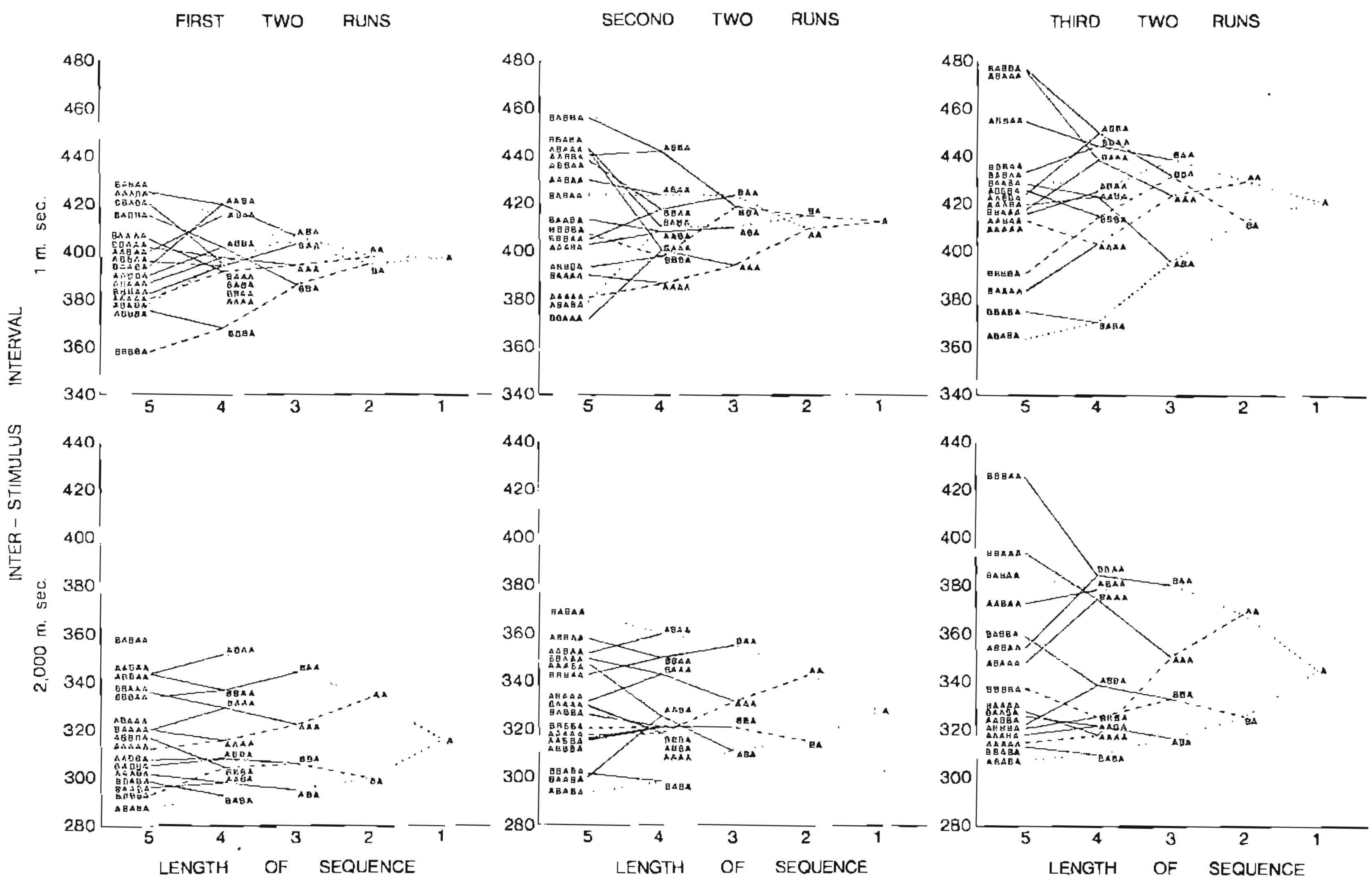

Fig. 5.2 Tree diagram analysis with RT in milleseconds for each interstimulus interval and for the first, second and third two runs.

Errors amounted to approximately 3.5% of the data and these and all RTs less than 50 msec. were excluded from the analyses.

It can be seen from the graphs that there is a tendency for the overall mean RT for both ISI conditions to increase across trials. However, a three way analysis of variance, comparing the mean RTs across trials with ISI and Ss as the other main factors showed no significant effect due to the number of trials, although there was a significant effect due to ISI. The interaction effect was not significant.

An examination of the differences between AA and BA shows that there was an alternation effect with the 2000 msec. interval which appears to change little over trials. In the 1 msec. condition, an initial overall alternation effect changes to a slight repetition effect in the second 200 trials and again is an alternation effect for the last 200 trials.

Inspection of individual results shows that for all Ss the RT to BA was faster than that to AA for the 2000 msec. condition for all blocks of 200 trials. In the 1 msec. condition, for all blocks of trials, three Ss produced repetition effects and two produced alternation effects. For one S, alternation effects were found for the first and third blocks and a repetition effect for the second. A three way analysis of variance, comparing the difference between AA and BA across ISIs and trials with Ss as the other factor, showed no significant effects.

In the 2000 msec. condition, it can be seen that there are higher order alternation effects.

In both higher order analyses of variance the remaining factor was first versus second verus third two runs.

The results of the higher order alternation analysis indicate a significant effect due to the comparison between differences involving alternation sequences and those involving the discontinuations of alternation sequences, indicating that the higher order alternation effects described above do occur. No other effects were significant.

Sequences of repetitions and the discontinuations of such sequences are shown by the dashed lines in the diagram. It can be seen that in the 2000 msec. condition, there are higher order repetition effects. It can also be seen that across runs the repetition effects tend to increase, RTs to AAAA and AAAAA being faster than those to BBBA and BBBBA by the third block of trials.

In support of the above observations, the only significant effects for the higher order repetition analysis were a significant main effect due to the comparison between the differences involving repetition sequences and those involving the discontinuations of repetition sequences, and a significant interaction between the significant main effect and the number of runs.

In the 1 msec. condition, for the higher order alternation effects, there is an overall tendency for RTs to decrease as the length of the alternation sequence increases, and to increase as the length of the alternation sequence immediately prior to its discontinuation increases. However, there are several exceptions to this and the effects are not as marked as in the 2000 msec. condition. For the higher order repetition effects, while there does appear to be a tendency for the RT to decrease as the length of the repetition sequence increases in length, there also appears to be a tendency for the RT to decrease as the length of the repetition sequence immediately prior to its discontinuation increases.

To test the higher order alternation and repetition effects in the 1 msec. condition, the same analyses of variance as those used for the 2000 msec. data were employed but none of the effects was significant.

DISCUSSION

The greater overall mean RT for the 1 msec. condition when compared with the 2000 msec. condition, can be explained by assuming that Ss in the latter condition have a longer time in which to recover from the previous response and in which to prepare for the next stimulus (e.g. Welford, 1959).

Although not significant, there is a tendency in both conditions for the mean RT to increase across trials. This could well be due to some short term fatigue.

Considering the first order sequential effects, those for the 2000 msec. condition are similar to those found in the previous experiments using the same ISI. Also, similar higher order alternation and repetition effects have been previously reported in the same experiments, with the exception of the change across trials for the higher order repetition effects. A similar change appears in the graphs of Experiment 1 but was not found to be significant. The effect could be explained in terms of greater familiarity over the 600 trials with the sequential structure of the stimulus sequence. That is, assuming on the basis of the gambler's fallacy phenomenon that Ss expect more alternations than repetitions, they might be expected to have become aware of the greater number of long runs of repetitions in the sequence across trials and to have prepared for them.

In Experiment 2, a first order repetition effect was found with an ISI of 50 msec. with higher order repetition effects. It was also found that a change in sequential effects with increasing ISI from a repetition to an alternation effect was a function of the number of trials. The presentation of 600 trials without a break in the 1 msec. condition of this experiment seems to have disrupted the Ss' performance, none of the first order or higher order effects being significant. A repetition effect was found for all blocks of trials for only three of the six Ss, the same number as produced a repetition effect in Experiment 3 with a 50 msec. ISI. It would seem then, given the aforementioned explanation of sequential effects in terms of both preparation and facilitation of repetition responses, that at low ISIs there is a conflict between the S's expectation and attempted preparation for alternations, and the automatic motor or coding facilitation of repetition responses. Over trials S may find it easier to decrease preparation for alternations and perhaps even to increase preparation for repetitions. This might explain in part the variability of performance across trials in the 1 msec. condition of this experiment. Short term fatigue, if such occurred, might also be expected to disorganize performance, producing the greater variability in the sequential effects which is observable across trials in the graphs of the 1 msec. condition.

It has been found in this and the previous experiments, that there is wide variability in the size of the alternation and repetition effects between Ss, so that it is not surprising perhaps that in some cases large alternation effects by only a few Ss should produce an overall first order alternation effect when the data is combined across Ss at low ISIs. Thus while first order alternation effects have been reliably found, repetition effects have not. An explanation for this could be partly in terms of the type of task; in this case quite a compatible one. Eichelman (1970) has pointed out that repetition effects have most often been found with tasks using symbolic displays, e.g. Hale (1967), and not with highly compatible tasks, e.g. Schvaneveldt & Chase (1969). However, as shown in Experiment 2, the number of trials also seems to be important.

CHAPTER VI.

INVESTIGATIONS OF AN EXPLANATION OF SEQUENTIAL EFFECTS IN TERMS OF BOTH EXPECTANCY AND PREPARATION AND OF A MOTOR OR CODING FACILITATION EFFECT.

So far the evidence has suggested an explanation in terms of guessing strategies involving preparation for both repetition and alternations, with the S anticipating more alternations than repetitions, and also in terms of some motor or coding facilitation.

In the next series of experiments it is proposed to test this explanation.

6.1. Experiment 5.

One way in which the explanation can be tested is by instructing Ss under one condition to prepare for a repetition of the last stimulus, and to get the S to try and respond as fast as possible to this stimulus while still responding as fast as possible within this limitation to the other stimulus. Under another condition, the S could be instructed to prepare for the other stimulus to that which had just occurred, that is, the alternation stimulus, and to try and make the RT to this stimulus as fast as possible, while still responding as quickly as possible within this limitation to a repetition of the stimulus. If the sequential effects at ISIs of greater than one second are simply due to expectation and preparation, it should be no more difficult to prepare for a repetition than for an alternation. In each case, the prepared RT should be shorter than the unprepared. For ISIs of less than one second, however, if the overall repetition effect is due to a motor or coding facilitation, this might be expected to interfere with attempts to prepare for an alternation response, so that while prepared repetitions should be faster than unprepared alternations, prepared alternations might not be as fast as unprepared repetitions.

The above procedure was carried out using ISIs of 2000 msec. and 50 msec.

METHOD

Subjects. The Ss were 3 male and 9 female volunteers. They were naive as to the aims of the experiment and ranged in age from 17 to 35 years.

Apparatus. The apparatus and stimulus sequences were the same as those used in the previous experiments.

Procedure Six Ss were assigned to the 2000 msec. condition, and the remaining six to the 50 msec. Ss attended three sessions, one on each of three consecutive days. In all conditions Ss were instructed to keep their error rate down to less than 5%. At the first session all Ss completed six runs of one hundred trials each. In the second session Ss were told that they would be given the same six runs of one hundred trials at the same ISI. However, for the first three runs, half the Ss in each condition were told to prepare for repetitions of the same stimulus, and to try to make the RTs to these stimuli as fast as possible, while still responding to the other stimulus as fast as possible within this limitation Similarly, the other half of the Ss were told to try and prepare for the stimulus other than the one which had last come on, that is, to prepare for alternations, making their RTs to these stimuli as fast as possible, but again making their RTs to repetitions of the same stimulus as fast as possible within this limitation. Those who for the first three runs prepared for repetitions were told, before the last three, to prepare for alternations and vice versa.

In the third session, the Ss in each of the ISI conditions were told that they would be given three runs of one hundred trials, which were the same as those to which they had previously responded with the same ISI. They were instructed to respond as fast as possible to whichever stimulus came on.

RESULTS

The data for the first six runs in session one were combined together, as were those for the three runs of preparation for repetitions, the three for preparation for alternations, and the three runs of session three. These are shown in Figure 6.1.

Errors amounted to approximately 7.5% of the data, and these and all RTs less than 50 msec. were removed from the analysis.

First order sequential effects

The difference between the RTs for AA and BA was tested in each condition by a related samples t test, except for the last three runs of the 50 msec. condition, where a Wilcoxon matched pairs signed-ranks test was more appropriate because of wide individual differences.

<u>2000 msec. conditions</u>. In the graphs it can be seen that for the first six runs there is an overall alternation effect. In the condition in which Ss prepared for repetitions, it can be seen that there is a repetition effect; in the preparation for alternations condition there is an alternation effect. Each effect was found to be significant. In the last three runs there is a repetition effect which was not, however, found to be significant, the difference being due in fact to only two Ss.

<u>50 msec. conditions</u>. In the graphs there is a repetition effect for the first six runs which, however, was not significant, two of the four Ss showing alternation effects. In the preparation for repetitions condition, there is a significant repetition effect. In the preparation for alternations condition there is also a repetition effect which was not found to be significant due to two Ss. For the last three runs there is again a repetition effect which was found to be significant, the RT to AA being faster than that to BA for all Ss.

<u>Higher order sequential effects</u>

Sequences of alternations and the discontinuations of such sequences are shown by the dotted lines in the graphs. Sequences of repetitions and the discontinuations of such sequences are shown by the dashed lines.

<u>2000 msec. conditions</u>. In the graphs for the first six runs it can be seen that the RTs for responses to alternations decrease as the length of the alternation sequence increases

and increase with length of the alternation sequence immediately prior to its discontinuation. However, the higher order alternation analysis, with no other factors, showed no significant effects. The higher order repetition effects are similar to the higher order alternation effects, but again the higher order repetition analysis showed no significant effects.

In the preparation for repetitions condition, there were no significant higher order repetition effects. For the higher order alternations, there was a significant effect due to length of sequence, and also due to the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences. From the graph, both these effects would seem to be due to the differences between the RTs for discontinuations of alternation sequences of different lengths, the differences between RTs increasing as the length of the alternation sequence immediately prior to its discontinuation increases.

For the preparation for alternations condition, none of the higher order alternation effects were significant. For the higher order repetitions, there was a significant effect due to the comparison between the differences involving repetition sequences and those involving the discontinuations of repetition sequences. From the graph this would largely appear to be due to the RTs for the repetition sequences decreasing as the length of the sequence increases.

For the last three runs there was a significant effect for the higher order repetitions, due to the comparison between differences involving repetition sequences and those involving the discontinuations of repetition sequences. There were no other significant effects. The same comparison was significant for the higher order alternation effects. Again, there were no other significant effects. From the graph it can be seen that the RTs for both repetitions and alternations decrease as the length of the sequence increases, and that the RTs for the discontinuations of both sequences increase with the length of sequence immediately prior to that discontinuation.

50 msec. conditions. For the first six runs combined, the only significant effect for the higher order repetition effects was that for the interaction between (a) the differences between length of sequence, and (b) the comparison between differences involving sequences of repetitions, and those involving the discontinuations of repetition sequences. From the graph it can be seen that this is due to the RT decreasing as the repetition sequence increases in length, while the RT to the discontinuation of the repetition sequences changes very little with increases in the length of the repetition sequence immediately prior to its discontinuation. It can be seen that the greatest difference is between the first and second higher order repetition effects while, due to the decrease in RT from BBA to BBBA, there is little difference between the second and third order repetition effects. There is also little difference between the RTs for BBBBA and BBBA and between the RTs for AAAAA and AAAA. For the higher order alternation effects, the only significant effect was that due to the comparison between differences involving sequences of alternations and those involving the discontinuations of alternation sequences. This is due to the decrease in RT as the alternation sequence increases in length and the increase in RT with length of the alternation sequence immediately prior to its discontinuation.

In the preparation for alternations condition, there were no significant higher order repetition or alternation effects. In the preparation for repetitions condition there was a significant effect for the higher order repetitions, due to the comparison between differences involving repetition sequences and those involving the discontinuations of repetition sequences. No other effects were significant. From the graph it can be seen that this is due to the progressive decrease in the RT to repetition sequences as the length of the sequence increases. There is little change in the RT to the discontinuations of repetition sequences from the first to the fifth order. There were no significant higher order alternation effects.

For the last three runs there were no significant higher order effects either for alternation or repetition RTs, although from the graph the RT for repetition sequences may be seen to decrease as the length of the sequence increases. However, the RTs for the discontinuations of repetition sequences also decrease slightly as the length of the repetition sequence immediately prior to its discontinuation increases which would tend to diminish the difference between the differences for repetition sequences and those for discontinuations of them.

While the RT for the discontinuations of alternation sequences increases with the length of the alternation sequence immediately prior to its discontinuation, the RT for alternation sequences first increases from BA to ABA and only then slightly decreases. This would tend to diminish the difference between the differences for alternation sequences and those for the discontinuations of alternation sequences.

Additional comparisons

Comparing the overall mean RT for the preparation for repetitions condition with that for the preparation for alternations condition revealed no significant difference by related samples t tests for either the 2000 msec. or 50 msec. conditions. In the 2000 msec. condition there was no significant difference between the RT for a prepared alternation and a prepared repetition. However, in the 50 msec. condition the RT for a prepared repetition was significantly faster than that for a prepared alternation, by a related samples t test.

DISCUSSION

The patterns of higher order sequential effects for both repetition and alternation RTs for the first six runs of both the 2000 msec. and 50 msec. conditions are similar to those found in the previous studies using the same ISIs.

The two conditions for the 2000 msec. ISI involving preparation show that all Ss were capable of producing either a repetition or an alternation effect. The lack of higher order effects for the prepared RT, whether repetition or alternation, suggests that preparation was complete within 2000 msec. However, from a comparison of the RTs for AA and BA with those for the first six runs, this appears to be largely due to an increase in the RT to the unprepared stimulus rather than involving both a decrease to the prepared stimulus and a corresponding increase to the unprepared. Thus it seems possible that Ss simply delayed their response to the unprepared stimulus.

In the preparation conditions for the 50 msec. ISI, all Ss were able to produce a repetition effect but only two Ss could produce an alternation effect. Also, unlike that for the 2000 msec. condition, in the 50 msec. preparation for repetitions condition, there are higher order repetition effects such that the RT continues to decrease as the sequence of repetitions increases in length. The latter result could be explained by assuming that preparation is not complete within 50 msec. But it would then be necessary to assume that, at low ISIs, increasing preparation for repetition has no effect on the RT to an alternation stimulus, since there is no change in the RT as the length of the repetition sequence immediately prior to its discontinuation increases. Nor would an explanation in terms of preparation alone explain the inability of some Ss to produce alternation effects. The results of both ISI conditions could be explained, however, by assuming that:

(1) for ISIs greater than approximately 1000 msec., sequential effects are determined solely by subjective expectancy and preparation, and

(2) for ISIs less than approximately 1000 msec. there is an automatic motor or coding aftereffect favouring repetition responses which increases with the number of repetitions and tends to out-weigh expectancy and preparation effects.

For the last three runs of the 2000 msec. condition there is a nonsignificant repetition effect which contrasts with the significant alternation effect of the first six. This could be due to the S's greater familiarity with sequences of both repetitions and alternations after having experienced the two conditions involving preparation instructions. If Ss do in fact prepare overall for more alternations than repetitions because of mistakenly assuming that there are more alternations than repetitions in a random sequence, then familiarity with the sequences provided by the two conditions involving preparation instructions might be expected to equalize the amount of preparation for each, leading to an insignificant first order but stronger higher order sequential effects. The statistical analyses support this, showing both significant higher order repetition and alternation effects.

Although not significant, in the 50 msec. condition there is a similar pattern of higher order repetition and alternation effects for the last three runs as that found for the first six and as found in Experiment 2 with a similar ISI. For the last three runs the first order repetition effect was found to be significant which, considering the above discussion of the equivalent 2000 msec. condition, might again suggest the operation of some automatic motor or coding facilitation of repetition responses.

6.2. Experiment 6.

Remington (1969) found, using a 2-choice task and an ISI of 4 seconds, a first order and higher order repetition effects. On the other hand, the first experiment reported in Chapter III of this thesis found a first order and higher order alternation effects using the same ISI. One possible explanation for this discrepancy lies in the different instructions given to the Ss. It has been suggested that alternation and repetition effects at higher ISIs are due to the S expecting and preparing for alternations and repetitions. It is known, as in the gambler's fallacy phenomenon, that Ss expect more alternations than actually occur in a random sequence. This would explain whey there should be an overall alternation effect for intervals of greater than one second. It seems at least possible that Ss might have been instructed in different ways in each experiment so that they prepared for more repetitions in one and more alternations in the other. In Experiment 1, Ss were told that both stimuli would be presented randomly an equal number of times while in Remington's, they were informed of "the probability associated with the appearance of each of the possible stimulus events in terms of percentages". It is unclear whether sequential probabilities or the probabilities of the two stimulus alternatives are being referred to, but, if it is sequential probabilities, it is possible that the information was given in such a way that Ss prepared for more repetitions than alternations.

In order to investigate the effect of subjective probability on the sequential effects in a 2-choice RT task, Ss in the following experiment completed three sequences of one hundred trials each, which were the same as those used in the previous experiment, that is, each of the two stimulus alternatives appeared equally often and the probability of a repetition was the same as the probability of an alternation. Before each session, however, the S was given different instructions concerning the sequential structure of the stimulus sequence. Before one session he was told that on 60% of the occasions of a presentation of a stimulus, the stimulus to be responded to would be the same as the previous stimulus, and 40% of the time it would be different; before another, that 60% of the time the stimulus to be responded to would be different to the preceding stimulus and on 40% of the time it would be the same; and before the other, that 50% of the time the stimulus would be the same as the preceding stimulus and that 50% of the time it would be different. If the Ss are influenced by what they are told about the properties of the sequences to which they respond, it might be expected that different sequential effects would be obtained for each of the conditions even though there were no objective differences in the sequential properties of the sequences.

An ISI of 2000 msec. was chosen because the results of Experiment 5 had shown that with this interval, Ss are equally capable of preparing for repetitions or alternations, without any significant change in the overall mean RT.

METHOD

Subjects. The Ss were 4 male and 2 female students enrolled for the Psychology I course at the University of Adelaide. They were naive as to the aims of the experiment and ranged in age from 17 to 25 years.

Procedure. Each S was assigned to one of the six possible orders of the three sets of instructions and attended on three consecutive days, completing one sequence of one hundred trials on each day. At each session, Ss were given one of the following sets of instructions concerning the structure of the stimulus sequences:

both of the stimuli will occur equally often and

(a) on 60% of the occasions of the presentation of a stimulus, the stimulus to be responded to will be the same as the preceding stimulus and on 40% of the occasions it will be different to the preceding stimulus,

(b) on 60% of the occasions of the presentation of a stimulus, the stimulus to be responded to will be different to the stimulus preceding it and on 40% of the occasions it will be the same,

(c) on 50% of the occasions of the presentation of a stimulus, the stimulus to be responded to will be different to the preceding stimulus and on 50% of the occasions it will be the same.

Before beginning each 100 trials the experimenter made sure that the S understood what was required and the supposed sequential structure of the particular stimulus sequence to which he was responding.

RESULTS

The data for each 100 trials were combined across Ss for each of the instruction conditions. The results are presented in the form of graphs shown in Figure 6.2.

Errors amounted to approximately 1% of the data and these and all RTs less than 50 msec. were excluded from the analysis.

It can be seen from the graphs that there is little difference between the three conditions. All show that the RT to BA is faster than that to AA. Related samples t tests showed that these differences were significant for both the 60% alternations condition and for the 50% repetitions condition, but not significant for the 60% repetitions condition owing to one S.

A two way analysis of variance comparing the overall mean RTs for the three conditions with Ss as the other factor showed no significant effects. A similar analysis of variance comparing the differences between AA and BA across the three conditions again showed no significant effects.

From the graphs it can be seen that for all conditions, generally RT decreases as the length of the alternation sequence increase and increases with the length of the alternation sequences immediately prior to its discontinuation. This is supported by the results of the higher order

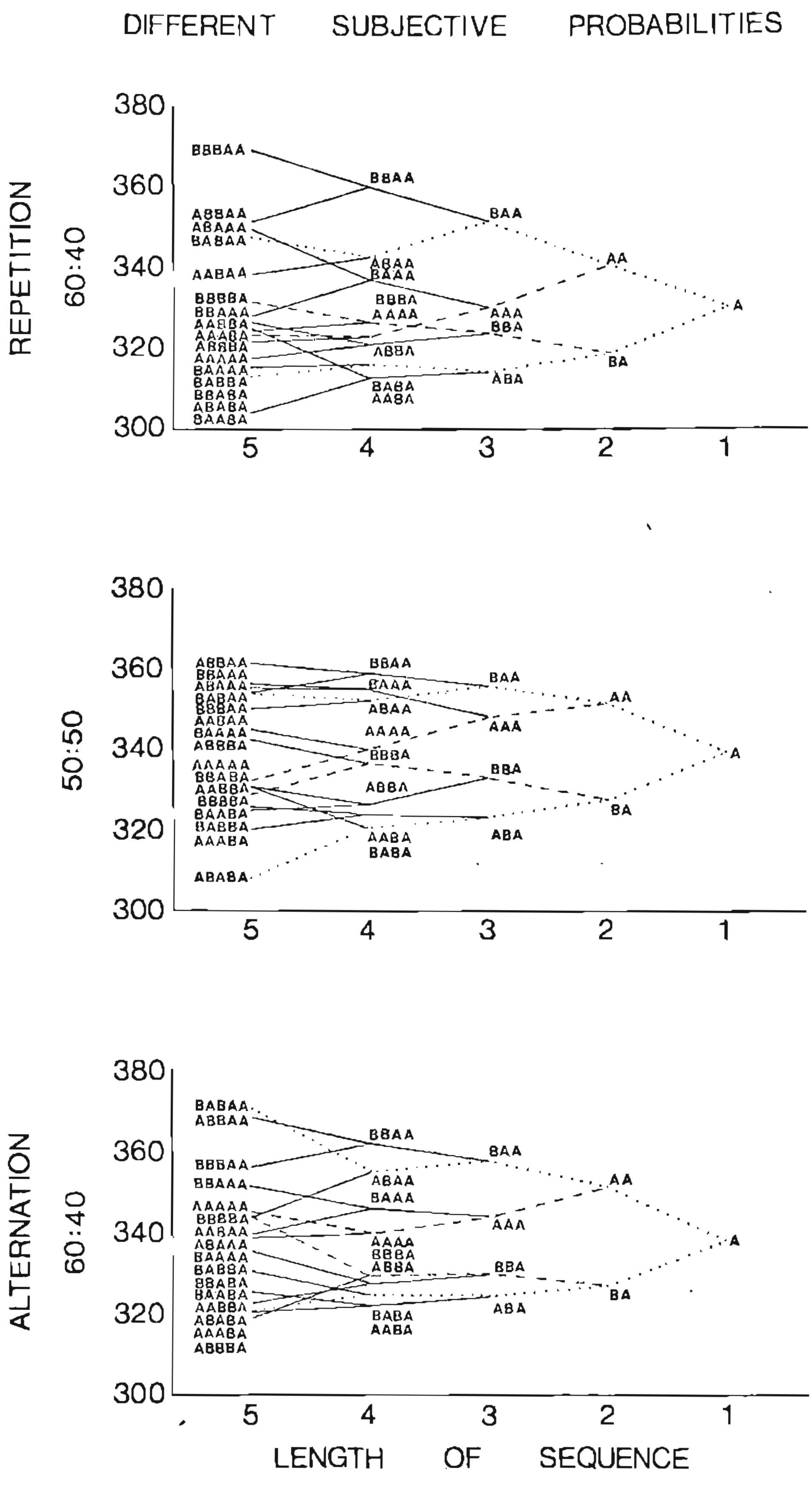

Fig. 6.2 Tree diagram analysis with RT in milleseconds for each different subjective probability condition.

alternation analysis, with Ss and the three different instructions conditions as the remaining factors, where the only significant effect was that due to the comparison between differences involving alternation sequences of different lengths and those involving the discontinuations of alternation sequences of different lengths.

Sequences of repetitions and the discontinuations of them are shown by the dashed lines in the diagrams. It can be seen that as for the higher order alternation effects, though not to the same extent, RT decreases with increase in the length of the repetition sequence and increases with length of the repetition sequence immediately prior to its discontinuation. It can also be seen that the higher order repetition effects, though slight, appear to be greatest in the 60% repetitions condition and least in the 60% alternations condition. The higher order repetition analysis, which was similar to that for the higher order alternations, supports these observations showing a significant main effect due to the comparison between the differences involving repetition sequences and those involving the discontinuations of repetition sequences, and also a significant interaction due to the significant main effect x the three different instructions conditions. No other effects were significant.

DISCUSSION

It is clear from the graphs and the analyses of the data that the effects due to the different instructions given to the Ss on different occasions were only slight, the only significant change being in the higher order repetition effects.

This is certainly not sufficient to explain the difference between the results of Remington (1969) and those of Experiment 1.

The pattern of sequential effects found in all three conditions was similar to that found using the same ISI in Experiments 1 and 2.

However, several criticisms can be made of the procedure used in the present experiment which might have prevented the required change from manifesting itself. First, only 100 trials were given for each condition which might not have been sufficient for a difference to show. This was thought to be necessary since too many trials would presumably give the S an opportunity of verifying whether or not the instructions had been correct. For the same reason, percentages of 60 and 40 were chosen for the biased conditions, hopefully not so different that it would be obvious to the S that the instructions were not correct, yet different enough subjectively for him to take note of them. Second, only six Ss were used, although Experiment 1 used only six and Remington (1969) only five. Third, and perhaps most important, Ss should probably have only encountered one of the different instructions conditions, since using the same Ss makes it more probable that they will realize that sequences with the same sequential properties are being used in each condition. However, an examination of the results of the first condition encountered showed no greater tendency towards an appropriate change in the sequential effects than any of the other results. Also, Ss were asked after the last session whether they had noticed the differences in the sequences. While a few said yes, most said no, but few of these seemed inclined to question whether there really had been any differences between the sequences.

The conclusion from the present results would appear to be then that the instructions given to the Ss are not likely to cause changes large enough to explain the difference in sequential effects between the results of Remington (1969) and Experiment 1.

6.3. Experiment 7.

Experiments in which the probability of repetitions and alternations have been altered have usually found that the first order effect, whether repetition or alternation, found with a random sequence has increased or decreased with the proportion of repetitions or alternations respectively.

According to the explanation of sequential effects suggested so far, this would be expected, at least for ISIs of greater than one second, to be due to the S increasing his preparation for the preponderant event. Since Ss seem to expect more alternations than repetitions in a random sequence, it might be expected that overall, alternation RTs would be favoured so that alternation and repetition effects produced by equal and opposite changes in the sequential structure might not themselves be equal and opposite. For ISIs of less than one second, the motor or coding facilitation might be expected also to have an effect, favouring repetitions.

In order to examine these explanations further, sequences of stimuli were constructed such that the first two thirds of them were biased in favour of either more alternations or repetitions while the last third consisted of a random sequence containing 50% repetitions and 50% alternations. The Ss were told that the whole of the sequence, which was given in one block, was biased either for repetitions or alternations whichever was the case. If Ss do prepare for stimuli, it might be expected that the effects would carry over to the last third of the sequence for ISIs of greater than one second. If, however, the effects were due to some automatic process dependent upon the stimulus, it would not be expected that there would be any difference between the three conditions for the results of the last third of the runs. On the basis of the explanation that has been suggested, since some but less preparation is assumed to take place at low ISIs than at high, it would be expected that there would be a greater change in the sequential effects from the first two runs to the last run in the low than in the high ISI condition.

Two ISIs were used, 2000 msec. and 1 msec. in order to produce first order alternation and repetition effects respectively for sequences equally balanced for proportions of repetitions and alternations. The higher order analysis was also carried out on the data of this experiment separating out the effects of all possible combinations of stimuli up to four in length. Only sequences of up to four in length were examined since there were not enough fifth order sequences of each type to give reliable comparisons.

METHOD

Subjects. These were 5 male and 7 female students enrolled for the Psychology I course at the University of Adelaide. They were naive as to the aims of the experiment and ranged in age from 17 to 25 years.

Stimulus sequences. Three stimulus sequences each of three hundred trials were constructed from blocks of 100 trials. These blocks were constructed from random number tables with constraints ensuring that both stimulus lights were presented equally often and for five of them further ensuring that equal numbers of repetitions and alternations were present, for two of them that there were 70% repetitions and 30% alternations, and for the remaining two that there were 70% alternations and 30% repetitions.

Procedure. Six Ss were assigned to the 2000 msec. ISI condition and the remaining six to the 1 msec. condition. Ss attended three sessions, one on each of three consecutive days. For both ISI conditions, each S was assigned to one of the six possible orders of the three difference sequences completing one of the sequences on each day. Ss were told that the sequence to which they would be responding would be such that both stimuli would be presented randomly an equal number of times in the three hundred trials and that either (a) 70% of the time the stimulus to be responded to would be the same as the preceding stimulus and 30% of the time it would be different, (REP condition), or (b) 70% of the time the stimulus to be responded to would be different to the preceding stimulus and 30% of the time it would be the same, (ALT condition), or (c) 50% of the time the stimulus to be responded to would be the same as the preceding stimulus and 50% of the time it would be different, (RAND condition). Care was taken in giving this information concerning the sequential structure of the stimulus sequence to ensure that Ss understood it.

RESULTS

The data for the first 200 trials and the last 100 trials were combined separately across Ss for each of the ISIs and different sequential probabilities conditions. The results are presented in the form of graphs in Figures 6.3 and 6.4.

Errors amounted to approximately 2% and these and all RTs less than 50 msec. were removed from the analyses.

2000 msec. condition.

It can be seen from the graphs that there is very little change in the overall mean RTs between the three different sequential probabilities conditions for either the first 200 or the last 100 trials. To test the significance of these effects a two way analysis of variance was performed on the mean RTs for the first 200 trials with Ss as the other factor. There were no significant effects. The same analysis performed on the results for the last 100 trials also showed no significant effects.

The same analysis of variance was used to test the significance of the differences between the differences between AA and BA across the three different sequential

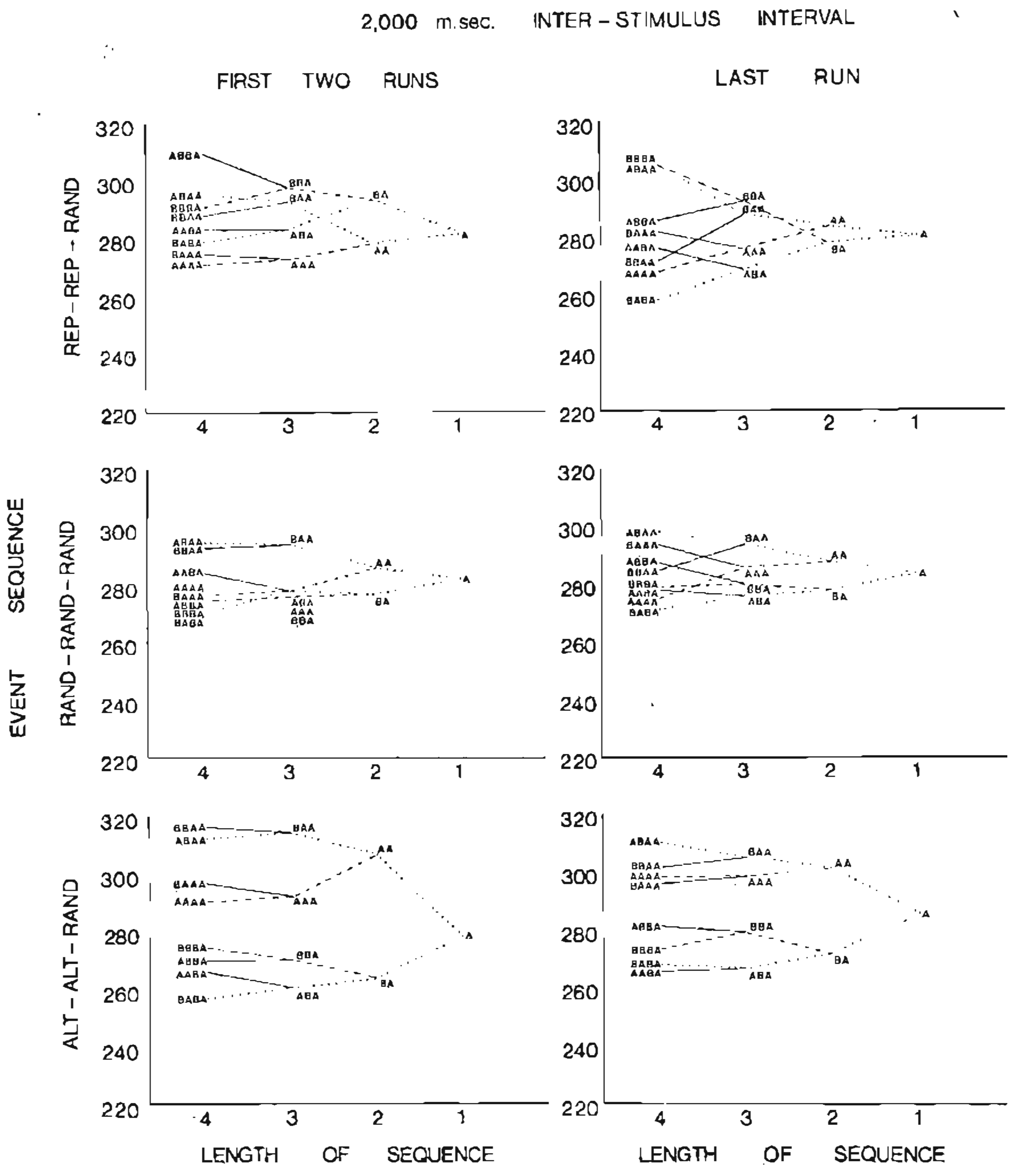

Fig. 6.3 Tree diagram analysis with RT in milleseconds for each event sequence and for the first two runs and the last run with an interstimulus interval of 2000 milleseconds.

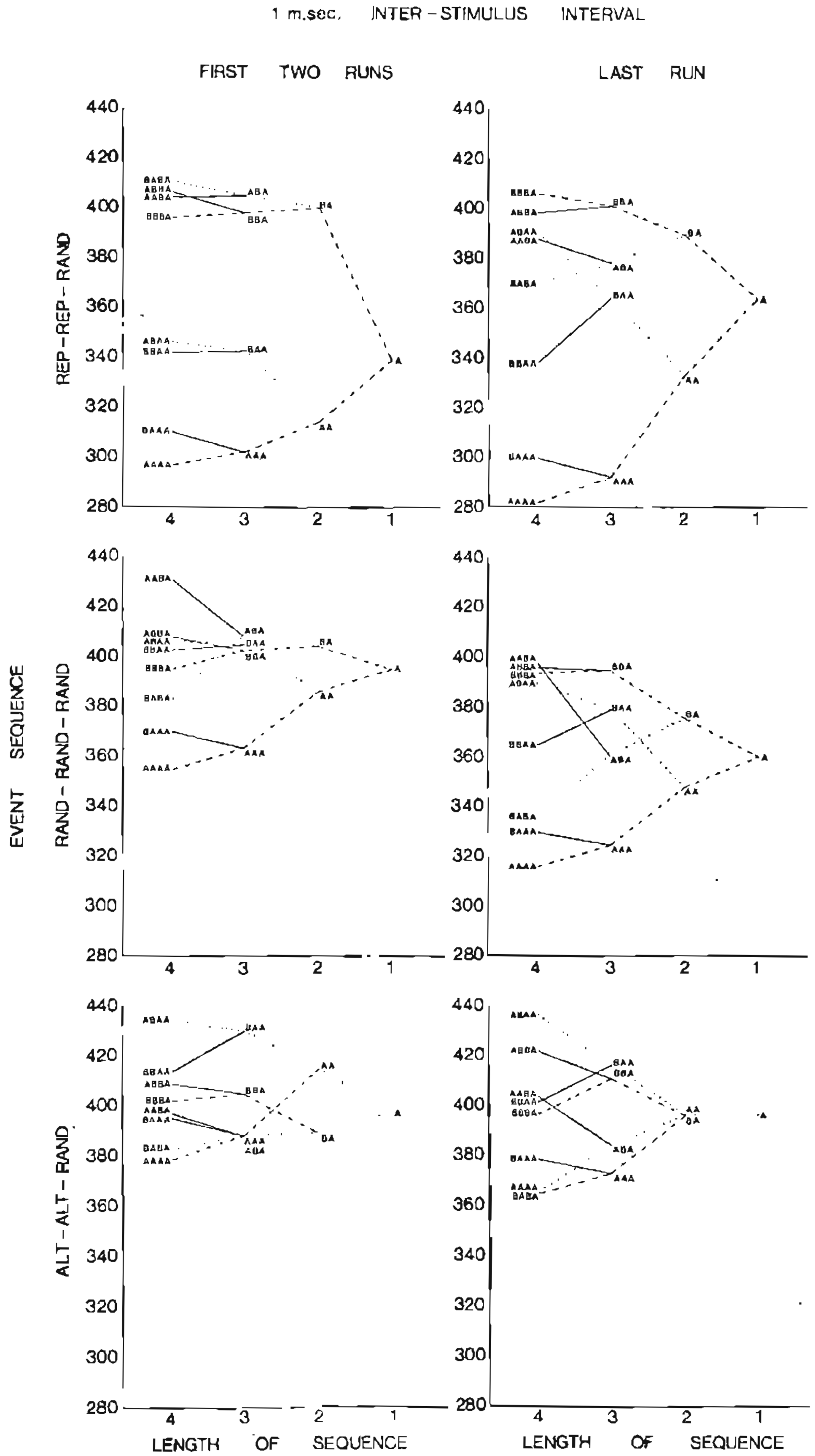

Fig. 6.4 Tree diagram analysis with RT in milleseconds for each event sequence and for the first two runs and the last run with an interstimulus interval of 1 millesecond.

probabilities conditions. For the first 200 trials, there was a significant effect due to the three different conditions, and the same analysis showed that the same effect was also significant for the last 100 trials. From the graphs it can be seen that for the first 200 trials, there is a large first order alternation effect for the ALT condition, a smaller alternation effect for the RAND condition and a small repetition effect for the REP condition. For the last 100 trials, there is little change in the RAND condition, a slight decrease in the ALT condition and a change from a repetition effect to a small alternation effect in the REP condition.

Sequences of alternations and the discontinuations of such sequences are shown by the dotted lines in the graphs For all the conditions of the first 200 trials it can be seen that there are higher order alternation effects. These appear to be more prominent overall between the second and third order RTs than between the third and fourth, and appear to be most pronounced for the ALT condition and least for the RAND condition.

The results of the higher order alternation analysis, with remaining factor the three different sequential probability conditions, support the above observations insofar as there is a significant effect due to the comparison between the differences involving alternation sequences and those involving the discontinuations of them. This was the only significant main effect. The only significant interactions were those between the significant main effect and the length of sequence, and between the main effect and the three different probabilities conditions.

The same analysis performed on the results of the last 100 trials again showed a significant main effect due to the comparison between the differences involving alternation sequences and those involving the discontinuations of alternation sequences. This was the only significant main effect. The only significant interaction was that between the significant main effect and the three different sequential probabilities conditions indicating that the higher order alternation effects change across the three conditions. From the graphs it can be seen that somewhat unexpectedly, the effects appear to be slightly greater in the REP condition.

Sequences of repetitions and the discontinuations of such sequences are shown by the dashed lines in the graphs.

From the graphs it can be seen that generally, there are higher order repetition effects. Using the higher order repetition analysis, with the remaining factor the three different sequential probabilities conditions, the only significant effect for both the first 200 trials and the last 100 was that due to the comparison between differences involving repetition sequences and those involving the discontinuations of repetition sequences.

The same analyses as those used for the 2000 msec. data were also used for the 1 msec. data.

1 msec. condition

Again an analysis of variance showed no change in the overall mean RTs across the three different sequential probabilities conditions for either the first 200 or the last 100 trials even though the graphs indicate a lower RT for the REP condition than for the RAND condition and little difference between the RAND and ALT conditions.

The analyses of variance comparing the difference between AA and BA across the three conditions showed a significant effect for both the first 200 trials, and the last 100 trials. The graphs indicate for the first 200 trials a first order repetition effect for the RAND condition, a larger repetition effect for the REP condition and an alternation effect for the ALT condition. There is little change in the last 100 trials for the repetition effect of the RAND condition, a decreased repetition effect for the REP condition and a decrease in the alternation effect to nothing in the ALT condition.

The higher order alternation analysis showed no significant effects for the first 200 trials while only the effect due to the comparison between differences involving alternation sequences and those involving the discontinuations of alternation sequences was significant for the last 100 trials. For the last 100 trials, it can be seen that there are higher order alternation effects, and that these effects are much more clear than over the first 200 trials.

The only significant main effect of the higher order repetition analysis for the first 200 trials was that due to the comparison between the differences involving repetition sequences and those involving the discontinuations of them. The only significant interaction was that due to the significant main effect x the three different sequential probabilities conditions. The graphs indicate that RTs decrease as the repetition sequence increases in length and that this is greatest, somewhat unexpectedly, in the ALT condition, but that there is little change in the RT to the discontinuations of repetition sequences as the length of the repetition sequence preceding its discontinuation increases. The analysis for the last runs similarly showed one significant main effect, that due to the comparison between the differences involving repetition sequences and those involving the discontinuations of repetition sequences. The only significant interaction was that due to the significant main effect x the length of sequence. As in the first 200 trials, the RT decreases as the repetition sequence increases in length and this appears to be more pronounced for the difference between the second and third order RTs, but unlike the results of the first 200 trials, there appears to be an increase in the RT with length of the repetitions sequence immediately prior to its discontinuation.

DISCUSSION

The graphs show very little difference between the overall means of the first 200 trials for the three 2000 msec. conditions and the analysis of variance indicates no significant difference between them. This result may be contrasted with that of Moss, Engel & Faberman (1967), who, using an ISI of 12 seconds, observed that the mean RT to sequences biased in a similar way to those in this experiment were longer than that to a random sequence. In explanation of this, they suggested that subjective expectancies may have been incorrect. Ss in their biassed conditions reported after the experiment that they had observed patterns in the stimulus sequence and had associated these with the particular stimulus either left or right when in fact these were equally probable. The authors suggested that if Ss were correctly informed of the balancing of the stimulus events the increases in the RT might disappear. The present results would support this suggestion.

The lack of a significant difference between the overall mean RT of the first 200 trials for the three 1 msec. conditions can be contrasted with the results of Bertelson (1961) who found with an interval of 50 msec. that the overall mean RT to a REP biassed sequence was significantly faster than that to a RAND sequence which did not differ from an ALT sequence. The amount of bias was only slightly more than that used in this experiment. Certainly the graphs of the present results indicate a much lower mean RT for the REP condition and little difference between the RAND and ALT conditions in agreement with Bertelson's findings. However, in the first of the two experiments reported in Bertelson's paper, he found that the difference was only significant after 5000 trials, although in the second experiment similar results were found after 2000 trials.

It has been previously shown, in Experiment 2, that the number of trials is important in obtaining the change from a repetition effect to an alternation effect with increasing ISI, suggesting that the S may take some time to adopt the most efficient strategy of responding.

As previously reported in the literature, there was a first order repetition effect for the first 200 trials of the 1 msec. RAND condition and a first order alternation effect for the first 200 trials of the 2000 msec. RAND condition. In the 1 msec. condition, these effects changed to a first order alternation effect and a larger repetition effect for the ALT and REP conditions respectively. This result is similar to that found by Bertelson (1961) with an interval of 50 msec. In the 2000 msec. condition, the overall first order alternation effect for the first 200 trials of the RAND condition changed to a first order repetition effect and a larger first order alternation effect for the REP and ALT conditions respectively. This result is similar to that found by Moss, Engel & Faberman (1967) with an interval of 12 seconds.

Comparing the last 100 trials across conditions, there was little change in the overall mean RT_S, with either ISI. The mean RT for the 1 msec. REP condition still appeared to be much lower than the corresponding RTs for the RAND and ALT conditions, but still was not significantly different from them. Again, for the 2000 msec. condition, there is little change across trials or between conditions, and again there is no significant difference between the REP, RAND and ALT conditions.

If the sequential effects were determined entirely by the structure of the stimulus sequence, it would be expected that there would be no significant differences between AA and BA between the REP, RAND and ALT conditions over the last 100 trials for either of the 1 msec. or 2000 msec. conditions, since the sequential structures of all these sequences were the same. The fact that differences between conditions apparent in the first 200 trials persisted into the last 100 trials, not so marked yet still significant, indicates that Ss were still tending to expect and prepare for what they thought was the more probable event, a repetition or an alternation. Also, the fact that differences persist for both ISI conditions indicates that some preparation on the basis of expectancy occurs at the 1 msec. as well as at the 2000 msec. ISI.

However, while there appears to be little change in the difference between AA and BA across trials for either of the RAND conditions, the graphs suggest much greater changes for the 1 msec. REP and ALT conditions between the first 200 trials and the last 100 than for the same changes in the 2000 msec. condition. This result would be expected if the effect of the sequential structure of the stimulus sequence was more important at low ISIs. At 2000 msec., it has been suggested that the sequential effects are due entirely to exepctation and preparation on the part of the S while at

1 msec. it has been suggested that there is some motor or coding facilitation of the repetition response which would depend for its effect on the proportion of repetitions in the sequence. However, the existence of higher order alternation effects at low ISIs shows that even here, expectation and preparation do occur. It seems reasonable to assume that there might also be some preparation for repetitions although the lack of change in the RTs for the discontinuations of repetition sequences suggests that this does not occur to any great extent.

It is evident both from the graphs and the analyses that higher order repetition and alternation effects occurred. In the 2000 msec. conditions, these are similar to those reported in Experiments 1 and 2, and support an explanation of sequential effects at ISIs higher than one second in terms of strategies of preparing for alternations and repetitions. The higher order effects for the first 200 trials of the 1 msec. condition are also similar to those reported previously except that there is very little in the way of higher order alternation effects for the REP condition. The higher order repetition effects are as previously reported, with lack of change in the RT for the discontinuations of repetition sequences suggesting some other explanation than that in terms of expectation and preparation, probably in terms of some motor or coding facilitation. For the last 100 trials, however, while there are higher order alternation effects for all conditions, the higher order repetition effects, particularly for the REP and RAND conditions appear to be like higher order alternation effects insofar as there is an increase in the RT as the length of the repetition sequence immediately prior to its discontinuation increases. Such a change suggests some preparation for repetitions and further suggests that while at low ISIs Ss may begin by expecting more alternations than repetitions, yet still producing an overall repetition effect due to the motor or coding facilitation, they may over time also begin to prepare for repetitions.

CHAPTER VII.

A MORE DETAILED ANALYSIS OF THE SEQUENTIAL EFFECTS IN AN 8-CHOICE REACTION TIME TASK

7.1. Experiment 8.

In previous experiments reported in the literature and in the experiments reported in the preceding chapters of this thesis, the higher order analysis of the sequential effects in 2-choice tasks has been essential in arriving at a more adequate explanation of both the repetition and alternation effects. Bertelson's (1963) explanation of the repetition effect and Williams' (1966) explanation of the alternation effect have been found to be inadequate in explaining the higher order sequential effects revealed by more detailed analyses of the data.

As was mentioned in Chapter I, following the discovery of the "repetition effect" in 2-choice tasks by Bertelson (1961), experiments concerned with sequential effects in 4- 6- or 8-choice tasks have usually divided the data into two mean RTs, one for repetitions, that is, for all stimuli following themselves, and the other for alternations or nonrepetitions, that is, for all stimuli following all other stimuli than themselves (for example, Rabbitt, 1968; Schvaneveldt & Chase, 1969; Keele, 1969).

This partitioning ignores a good deal of potential information. It has already been pointed out (Alegria & Bertelson, 1970; Welford, 1971) that in 8-choice tasks the RTs for individual stimuli can be significantly different. Hence the question arises as to whether sequential effects might also differ amongst different sequential combinations of stimuli. In order to investigate this question sequences were constructed which could be analysed into an 8 x 8 matrix allowing a comparison of the mean RTs for each stimulus following every other stimulus in an 8-choice task.

This analysis enables several questions to be answered. For example, can an overall repetition effect be further broken down into hand and finger repetition effects; what is the relative contribution of each; and do they differ depending on the position of the particular stimulus in the display? Are there also proximity effects in the sense that a stimulus close to an immediately preceding stimulus is responded to faster than stimuli further removed? Answers to these questions might be expected to throw some light on the cause of the repetition effect in 8-choice tasks. Two explanations that have been suggested are, first, in terms of a facilitative aftereffect of the response such that the RT to a repeated stimulus is decreased due to the effects of having just responded to that stimulus. This explanation has taken two forms, (a) in terms of a physiological activation effect which continues, and (b) due to some portion of a complex coding or decoding operation which does not have to be done again. The second is in terms of the application of particular sequential processing strategies where the S is assumed to prepare for the occurrence of a particular stimulus (e.g. a repetition of the immediately preceding stimulus) on the basis of some expectation, or to check the stimuli in the display in a particular order for the correct stimulus.

Recent evidence (Welford, 1971, 1973) has favoured an explanation of multiple choice RTs in terms of a serial dichomitisation or trichomitisation process in which the S is assumed to arrive at the correct signal and choice on each occasion by a series of inspections. He is assumed to divide the display into two or three groups of stimuli and inspect each group in turn for the correct signal. If it occurs in the group he inspects first, he divides that group into two or three smaller groups and again inspects each of them in turn. If the correct signal is not in the group first inspected, the S is assumed to check the remaining groups until he positively identifies the group in which it does occur, before proceeding to divide that group into two or three smaller groups. In an 8-choice task with compatible S-R arrangements, Welford found that the inner fingers of each hand, that is, the middle and ring fingers responded more slowly than the outer fingers, that is, the index and little fingers. This difference was apparently due to perceptual factors because when the outer stimuli were paired with the inner instead of the outer fingers and vice versa, RTs to the outer stimuli were still shorter than those to the inner. Welford accounted for this finding by assuming that whenever the S has to decide between an outer and an inner stimulus, he tends to inspect the former before the latter. However, the model allows for some flexibility in the types of strategy that may be adopted and certainly does not preclude the possibility that other more subtle sequential effects may also influence performance.

Since the ISI has been shown in previous research with 2-choice RT tasks to affect sequential effects (Bertelson, 1961; Hale, 1966; and the preceding experiments reported in this thesis), two ISIs were used in this experiment.

METHOD

Subjects. The *S*s were 3 male and 3 female volunteers enrolled for a first year Psychology course at the University of Adelaide. Their ages ranged from 18 to 25 years and they were naive as to the aims of the experiment.

Apparatus. The display consisted of a 20 cm square, flat blackboard in which was set eight 16 mm diameter neon bulbs. These were arranged in a horizontal row at 22 mm intervals. A vertical white line separated the lights into two groups of four. Each *S* was tested individually, sitting at a table 2.8 metres in front of the display and operating 8 morse keys with flat tops, arranged in two arcs of 4 placed so as to be convenient for the two hands. The lights and keys were not labelled but will be referred to as if numbered 1 to 8 in order from left to right. Each light was responded to by pressing its corresponding key. The allocation of fingers to keys was in order from 1 to 8, left little finger, left ring, left middle, left index, right index, right middle, right ring and right little fingers respectively. A pressure of approximately 140 gms was required to operate the keys. RT was recorded in milleseconds from the onset of the stimulus to the depression of any of the keys. The ISIs used were, as measured from the release of any key to the onset of the next stimulus, 1 millesecond and 2000 msecs.

Stimulus sequences. Three runs were prepared, each beginning with four stimuli, reactions to which were not scored, followed by 192 stimuli arranged in three blocks of 64, each block containing in a random order, one of every possible combination of each stimulus following every other stimulus. In addition, 16 practice trials, not included in the results, preceded each run.

Procedure. Three of the Ss completed each of the three stimulus sequences for the 2000 msec. condition on one day followed by the same three sequences for the 1 msec. condition on the next. The other three Ss completed the two conditions in the reverse order. The Ss were told that they were participating in an 8-choice RT experiment and that their task was to respond as quickly as possible to whichever stimulus light came on by pressing the appropriate key, keeping the number of errors down to less than 5 percent. They were informed of the ISI before each session and were told that the stimuli would be presented in a random order. The three different sequences were presented in a random order, and there was a rest period of approximately 2 minutes between each sequence. The stimuli were presented and the data recorded by means of computer program paper tapes. Errors amounted to approximately 6 percent. These and all RTs of less than 100 msecs. were omitted from the analyses.

RESULTS AND DISCUSSION

Table 7.1 shows the mean RTs for repetitions and alternations as they have usually been measured in previous experiments in the literature. It can be seen that the

Table 7.1: Mean RTs for repetition and alternation responses.

	Interstimulus interval	
RESPONSE	1 msec.	2000 msec.
Different from previous response	687	599
Same response as previous response	613	531
Difference	74	68

repetition effect for the 2000 msec. condition appears to be slightly less than that for the 1 msec. condition. However, this difference was not significant by a related samples t test.

Tables 7.2 and 7.3 show the mean RT for each stimulus when preceded by each other stimulus for both the 1 msec. and 2000 msec. conditions.

One way of condensing the 8 x 8 matrices is by combining the mean RTs for both hands for each of the four fingers, whether little, ring, middle or index:

(1) when it is a repetition, that is, it follows itself (REP),

(2) when it follows a response by a finger of the same hand but is not a repetition (SHNR), and

(3) when it follows a response by a finger of the other hand (OH).

These mean RTs are joined by the lines shown in Figure 7.1 for both the 1 msec. and 2000 msec. conditions. Also

Table 7.2: Mean RTs for 2000 msec. condition

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	Means
1	509	540	522	507	544	549	540	499	526
2	627	576	557	606	648	657	685	678	629
3	658	635	566	575	648	671	719	651	640
4	538	522	537	477	514	541	555	572	532
5	606	570	621	589	497	597	590	579	581
6	736	699	695	691	619	548	602	688	660
7	649	657	663	692	611	586	570	583	626
8	505	553	552	517	510	527	540	503	526
Means	604	594	589	582	574	584	600	594	590

Table 7.3: Mean RTs for 1 msec. condition

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	Means
1	582	572	618	541	584	618	636	577	591
2	626	632	572	676	758	765	766	784	697
3	789	700	598	614	733	786	848	830	736
4	684	646	622	604	605	605	664	638	634
5	726	696	691	652	622	611	697	710	676
6	912	842	835	767	644	660	621	781	758
7	778	755	879	803	738	588	614	643	725
8	589	620	684	643	584	568	585	604	610
Means	710	683	687	663	659	650	679	696	678

included in the graphs are the RTs which constitute each of these mean RTs. These are indicated by letters each of which represents the preceding response whether little (L), ring (R), middle (M), or index (I) of the same hand or of the other hand.

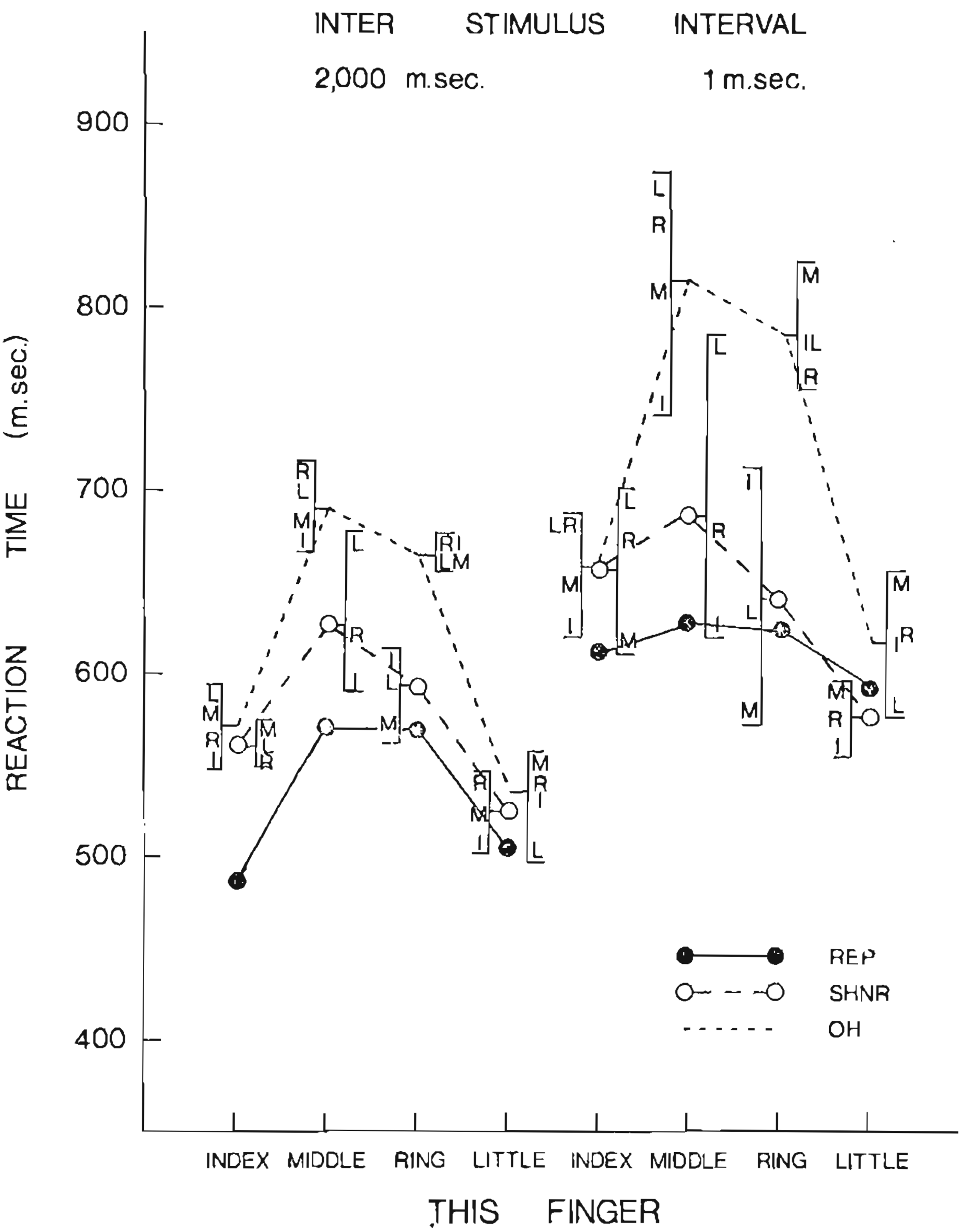

Fig. 7.1 Mean RTs in milleseconds for the two inter-stimulus intervals for the index, middle, ring and little finger responses when each, 1) is a repetition of the last response (REP), 2) follows a response by a finger of the same hand but is not a repetition (SHNR) and, 3) follows a response by a finger of the other hand (OH). Also shown are the RTs which constitute each of these mean RTs. These are indicated by letters each of which represents the preceding response whether little (L), ring (R), middle (M), or index (I) of the same hand or of the other hand.

Duncan multiple comparison analyses were used to compare the little, ring, middle and index REP, SHNR and OH RTs. Tables and significance levels for all the analyses are shown in Appendix 7.3. Any difference referred to as significant in the text will be at least with $p < .05$.

2000 msec. ISI condition

It is clear that, as was found by Welford (1971), the RTs for Inner finger responses, that is, middle and ring, are slower than those for Outer finger responses, that is, little and index. Comparing the four fingers, for both REP and OH responses the only significant differences in each case were those between either of the Inner when compared with either of the Outer responses. For the SHNR responses the middle finger RT was significantly different from both the little and index finger RTs, but the ring finger RT was significantly different only from the little finger RT.

It can also be seen that the repetition effect tends to be greater for the Inner fingers than for the Outer although only when REP RTs are compared with OH RTs. Considering the differences between REP, SHNR and OH responses, for the little finger it is clear that there is little difference in RT between these conditions, none of the differences being significant. For the index finger the pattern is similar except that the REP RT is significantly faster than the rest. For both the ring and middle fingers the REP RTs are fastest but there are no significant differences between these and the SHNR RTs. However, there are much larger differences between SHNR and OH RTs both of these differences and the differences between REP and OH being significant.

The partitioning of the overall mean RT into REP, SHNR and OH RTs would seem to be justified insofar as there seems to be little difference between the RTs, whether L, R, M or I, which constitute each of the OH Outer, each of the OH Inner and each of the SHNR Outer mean RTs. The one exception would seem to be the SHNR Inner mean RTs particularly where the middle following L RT seems to be substantially longer than the remaining SHNR middle RTs.

The fact that there are significant differences between the REP, SHNR and OH conditions, indicating that there are separate effects due to a repetition of the same hand as well as of the same finger, is compatible with an explanation of the sequential effects in terms of either a facilitative aftereffect or a saving in coding time since this could be explained by assuming either a spread of the facilitative aftereffect to the same hand as that involved in initiating the last response or a saving in coding the required hand for the next response.

However, the fact that the repetition effects exist mostly for the inner fingers is incompatible with an explanation in terms of a facilitative aftereffect since it would be expected that all fingers would be benefitted equally. An explanation in terms of a saving in coding time could perhaps be made by assuming that the inner fingers require extra coding and it is this which is saved.

<u>1 msec. ISI condition</u>

The same analysis as that used for the 2000 msec. condition was also used for the 1 msec. condition. It can be seen from the graph that the overall pattern of RTs is similar to that of the 2000 msec. condition insofar as once again the repetition effects seem to be greatest for the Inner fingers. There are no significant differences between REP, SHNR and OH responses for either of the two Outer fingers and only between SHNR and OH and REP and OH responses for the two Inner fingers. Once again this would seem to be incompatible with an explanation in terms of a facilitative aftereffect. However, three differences from the 2000 msec. condition may be noted:

(1) the differences between the Inner and Outer OH responses seem to be slightly larger. The differences are again significant between either of the Outer fingers and either of the Inner fingers.

(2) all the REP responses are very similar whereas in the 2000 msec. condition the Inner REP RTs were longer than the Outer. This also tends to be true of the SHNR responses there being no significant differences between the REP responses nor between the SHNR responses of any of the four fingers,

(3) generally, stimuli adjacent to the last stimulus are responded to almost as fast, and sometimes faster than, a repetition of the last stimulus (for example, middle following R when compared with middle following L). In the 2000 msec. condition, these RTs all tend to be longer

than the REP RT. It may also be noted that both middle following L and ring following I responses tend to be longer than the remaining SHNR RTs.

In order to investigate this apparent proximity effect the mean RT for all REP responses was compared with that for all responses to stimuli immediately adjacent to the last stimulus. These means and their differences for both the 1 msec. and 2000 msec. conditions are shown in Table 7.4. Each difference was tested by a related samples t test and was found to be significant for the 2000 msec. condition but not for the 1 msec. condition.

Table 7.4: Proximity Effects.

	2000 msec.	1 msec.
RT to response adjacent to repetition response	579	618
RT to repetition response	531	614
Difference	48*	4

*Significant $p < .02$

The proximity effect could be explained in terms of a facilitative aftereffect by assuming that the effect may spread to adjacent fingers. Its absence in the 2000 msec. condition could be explained with the additional assumption that the effect decays with time. A saving in coding time, however, would require some additional explanation.

Models

The 2-choice results were explained in terms of:

(1) subjective expectancy and preparation on the part of the S, and

(2) a facilitative aftereffect of the last response.

While a facilitative aftereffect can explain both the proximity effect and the fact that there are differences overall between REP, SHNR and OH responses it cannot explain the differences between the repetition effects for Inner and Outer responses. As far as preparation and expectancy are concerned, it might seem less likely that the S in an 8-choice task would prepare for a repetition since its probability of occurrence is only .125. Nevertheless there could be some preparation for the stimuli of a particular hand although, if any such preparation occurred one would expect some advantage of the Outer as well as the Inner SHNR and REP responses over their OH equivalents.

An explanation of the above results in terms of the model put forward by Welford (1971) would require certain modifications to its assumptions. If, for example, it were the case that all REP RTs were faster than all SH RTs which were in turn faster than all OH RTs, this could easily be accounted for by assuming that the S biases his inspections, first toward REP stimuli, then SH stimuli and then OH stimuli, although still, when faced with an Inner and Outer stimulus, checking the Outer before the Inner. According to this strategy, the S might be expected to be attending still in the 1 msec. condition to the last stimulus or SH stimuli when the next stimulus arrives. He would be expected to do so to a lesser extent in the 2000 msec. condition as there would be time for attention to be changed to OH stimuli on some occasions. If so, REP and SH RTs would be relatively faster in the 1 msec. than in the 2000 msec. condition, but at the cost of relatively longer OH RTs.

However, the results indicate that while such sequential biasing would explain the differences between Inner finger RTs in the two conditions, it would not explain those for the Outer, particularly the little finger, since for these there is little difference in RT regardless of which stimulus precedes it. Both the lack of difference between the RTs for Inner and Outer REP responses and the proximity effect in the 1 msec. condition would also need to be explained, as would the fact that, as indicated in Figure 7.1, middle following L responses and to some extent, ring following I responses for both ISI conditions seem to be nearly as long as the OH RTs.

An alternative explanation is to assume that basically the S first attends to the particular stimulus and then locates it in the display by seeking the nearest of a number of reference points. These might be:

(1) the ends of the display,

(2) the midline (this might be a real or imaginary midline),

(3) if the ISI is short enough, the position of the last stimulus responded to.

On this view Ss would locate little and index stimuli quickly, regardless of the position of the previous stimulus, as being next to either an end of the display or the middle of it. Middle and ring stimuli would need to be located as next to a little or index stimulus except when they are repetitions of the previous stimulus and hence reference points themselves. The proximity effect in the 1 msec. condition might be accounted for by assuming that the S is able to use the position of the last stimulus as a guide to the position of the adjacent stimulus if the ISI is short enough. If the position of the last stimulus is dependent on a memory trace which fades with time, similar to that postulated by Bertelson (1963), it might be expected not to operate to the same extent as a reference point after 2000 msec. There would thus be less shortening of RT to adjacent stimuli and an increase in the inner REP RTs. If SH responses are less overall than OH responses due to the use of the last stimulus as a reference point for repetition responses and for responses to stimuli immediately adjacent to the last stimulus, this would also explain why middle following L responses and to some extent ring following I responses tend to be closer to the OH RTs since in both these cases the last stimulus would not be an adjacent stimulus and hence they would have to be located in the same way as an OH Inner stimulus. The fact that the REP RT for the index finger is significantly faster than its SHNR and OH equivalents could be due to the midline not being as clear a reference point (since it has a stimulus light on each side of it) as the ends of the display. Hence a repetition of the index stimulus might be expected to be a better reference point for an index response than the midline thus accounting for the REP index response being faster than the SHNR and OH index responses. Such a difference in the relative efficiency of the midline and ends of the display as reference points might also account for the fact that the middle following L response appears to be slower than the ring following I response. In the latter case the end of the display is the more likely reference point to be used, in the former, the midline.

The above explanation assumes that basically the repetition effect in an 8-choice situation is due to a saving in identifying the stimulus, the greater effect for the Inner stimuli being due to the fact that, for non repetitions, these stimuli take longer to identify than their Outer equivalents.

Assuming a decaying memory trace of the position of the last stimulus would seem to imply an overall decrease in the repetition effect as the ISI increases. As previously pointed out, there is a decrease but it was not found to be significant. However, the usual method of measuring the repetition effect might now be seen to obscure the real repetition effect since:

(1) only some stimulus positions benefit from a repetition of the previous stimulus, and

(2) responses to repeated stimuli are not the only ones to benefit from a repetition of the previous stimulus, those immediately adjacent also benefiting. In fact there would seem to be a substantial increase in the repetition effect with the decrease in ISI if the Inner repeated responses are compared with the inner OH responses although this effect was only found to be significant by a one tailed related samples t test with $p < .05$.

Overall, the mean RT for the 1 msec. condition is longer than that for the 2000 msec. condition and since all RTs are in fact longer in the 1 msec. condition, it is presumably due to some constant factor which affects all RTs. Three possible explanations have been suggested (Welford, personal communication). Either:

(1) the time needed to obtain an optimum preparation,

(2) the time needed to recover from responding to the last stimulus, or

(3) the time needed to monitor the last response.

No decision in favour of any one of these can be made on the basis of the present results.

In conclusion, the above results do not support an explanation of sequential effects in 8-choice RT tasks in terms of some facilitative aftereffect. Nor do they support an explanation in terms of a simple sequential processing strategy. They do seem, however, to offer some support for an explanation in terms of a saving in stimulus identification time due to the last stimulus acting temporarily as a reference point.

As with the 2-choice higher order analysis, it would seem profitable to apply the analysis used in the present experiment to experimental situations in which the effects of other variables are examined. In the next chapter, an experiment will be described comparing compatible and incompatible S-R arrangements in an 8-choice task.

CHAPTER VIII.

SEQUENTIAL EFFECTS IN AN 8-CHOICE SERIAL RT EXPERIMENT USING COMPATIBLE AND INCOMPATIBLE STIMULUS-RESPONSE (S-R) ARRANGEMENTS

Experiment 9

The following experiment was designed to compare compatible and incompatible S-R arrangements in an 8-choice task using an ISI of 500 msec. The incompatible arrangement used was similar to that used by Welford (1971), that is, each outer stimulus was responded to by its adjacent inner response and each inner stimulus by its adjacent outer response.

On the basis of the explanation proposed in the preceding chapter, predictions can be made concerning the type of changes that might be expected to occur in the sequential effects. Since an ISI of 500 msec. was used, results somewhere between those for the 1 msec. and those for the 2000 msec. conditions of the last experiment were expected for the compatible condition and the major repetition effect was again expected to be between Inner SHNR and OH response RTs. However, it could have been expected that for the incompatible condition, most of the repetition effect would lie between REP and SHNR inner and also outer responses since for all non-REP responses, Ss would have to use the S-R code, only for REP responses being able to bypass it. This is because if the stimulus being responded to was adjacent to the last stimulus responded to, it would not under the incompatible conditions mean that the appropriate response was necessarily adjacent to the last response, thus necessitating the use of the S-R code. One might therefore not expect a proximity effect under these conditions although there may still be some advantage of the SHNR over the OH responses, since stimuli adjacent to the last stimulus responded to may still be easier to locate than those further removed.

Subjects. The Ss were 2 male and 4 female volunteers from the Psychology I course at the University of Adelaide. They were naive as to the aims of the experiment. Ages ranged from 17 to 30 years.

Method. The apparatus and stimulus sequences used were the same as those for the previous experiment. The allocation of fingers to keys with the both hands compatible arrangement (CC) was in order from 1 to 8, left little finger, left ring, left middle, left index, right index, right middle, right ring and right little fingers respectively. For the incompatible S-R arrangements there were two conditions, the first (II) in which lights 1 to 8 in order were responded to by the left ring, left little, left index, left middle, right middle, right index, right little and right ring fingers respectively and the second (CI) in which the left hand responded to the lights 1 to 4 in a compatible arrangement and the right hand to lights 5 to 8 in an incompatible arrangement as above. The ISI was 500 msec.

Procedure. The Ss attended on two consecutive days completing two of the three conditions on the first day and the third condition on the second. Each S was assigned to a different one of the six possible orders of treatments. They were told that they were participating in an 8-choice RT experiment and that their task was to respond as quickly as possible to whichever stimulus light came on with the appropriate finger, keeping their errors down to less than 5%. In each condition the particular S-R arrangement was explained before the commencement of the session. A series of 16 practice trials, not included in the results, preceded each run of stimuli. Ss were informed of the ISI and were told that the stimuli would be presented in a random order. Two of the three different stimulus runs were randomly assigned to each S-R condition. There was a rest period of approximately two minutes between each run. Errors amounted to approximately 6%. These and all RTs less than 100 msecs. were omitted from the analyses.

RESULTS

The 8 x 8 matrices for each condition are given in Appendix 8.4.

Figures 8.1 and 8.2 show in the same way as Figure 7.1 for each finger, with both hands combined, the mean RTs for the three classes of response:

(1) when it is a repetition (REP), that is, it follows itself,

(2) when it follows a response by a finger of the same hand but is not a repetition (SHNR), and

(3) when it follows a response by a finger of the other hand (OH).

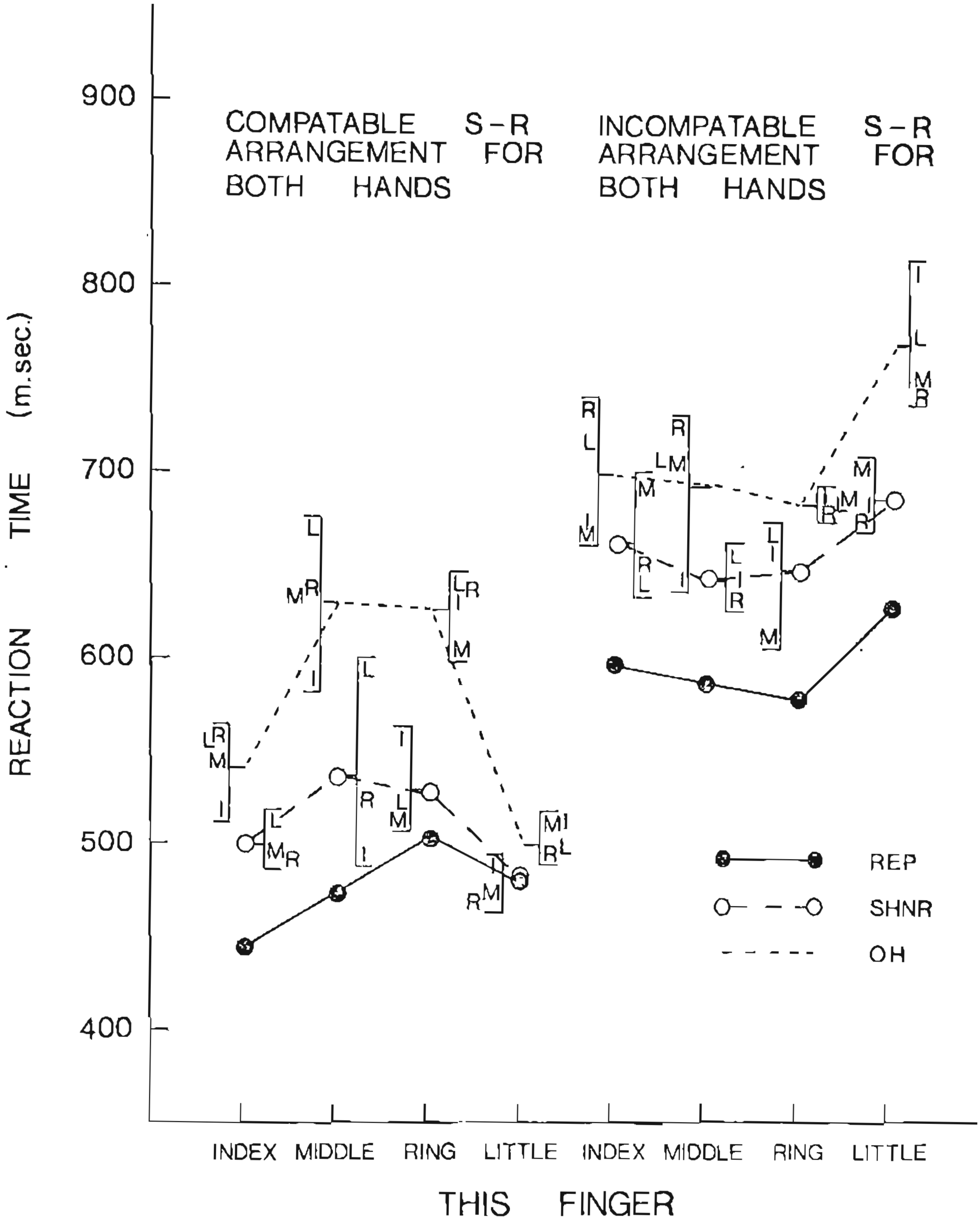

Fig. 8.1 Data (similar to that set out in Fig. 7.1) for the compatible and incompatible S-R arrangements for both hands.

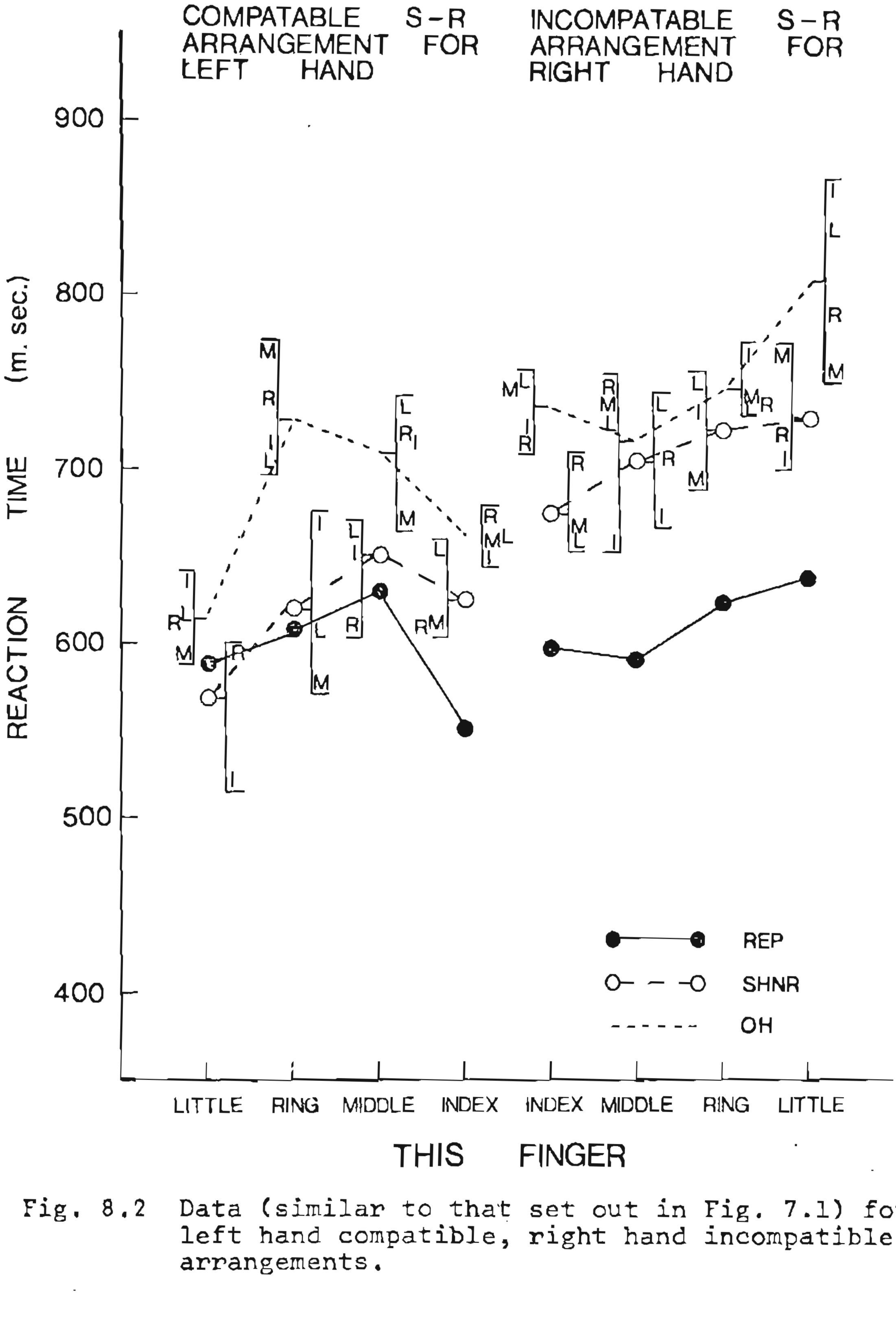

Fig. 8.2 Data (similar to that set out in Fig. 7.1) for the left hand compatible, right hand incompatible S-R arrangements.

Also shown are the RTs which constitute each mean RT. These are indicated by letters each representing a previous response either by a finger of the same hand or of the other hand.

To test these differences Duncan multiple comparison analyses were used comparing REP, SHNR and OH responses for the four different fingers in the CC and II conditions. In the CI condition, in order to reduce the number of comparisons, mean RTs for compatible and incompatible REP, SHNR and OH Inner (that is, middle and ring fingers combined) and Outer (that is, index and little fingers combined) were compared. This combining does some injustice to differences between index finger responses since these are now combined with those by the little finger, but the middle and ring finger responses seem quite similar. The full results are shown in Appendix 8.3. Any difference referred to as significant in the text will be with at least $p < .05$.

Compatible conditions

The RTs for the Inner fingers of each hand are generally slower than those for the Outer, as was found by Welford (1971). For the CC condition, the only significant differences between the OH responses were those between either of the two Inner fingers when compared with either of the two Outer and between index and little. For the SHNR responses, the only significant differences were those between middle and little, and ring and little finger responses. For the REP responses there was little difference between any of the RTs for the four fingers, the only significant difference being between the ring and index fingers. For the CI condition there were significant differences between Outer and Inner responses for the REP and OH responses but not for the SHNR.

It can also be seen that repetition effects tend to be greater for the Inner fingers. For the CC condition, there were no significant differences between the REP, SHNR and OH little finger RTs, but there were between SHNR and OH and REP and OH for the ring finger RTs. For both the index and middle fingers, there were significant differences between REP and SHNR and also between SHNR and OH RTs. For the CI condition the only significant differences were those between the Outer REP and OH responses and for the Inner responses between SHNR and OH, and between REP and OH.

Considering the RTs which constitute the mean RTs for the REP, SHNR and OH conditions for each of the four fingers there does seem to be a proximity effect in that RTs to stimuli immediately adjacent to the last stimulus are usually responded to as fast as and sometimes faster than repetitions. To test this, the overall REP RT was compared with the mean RT for responses to stimuli immediately adjacent to the last stimulus. These RTs and the differences between them are shown in Table 8.1. Using related samples t tests there were no significant differences for either of the compatible conditions shown in the first and third columns.

It is evident that the results for the CC condition in the present experiment are similar to the 1 msec. data of the previous experiment insofar as there is little difference between the REP responses for the four fingers and also as there seems to be a proximity effect.

Table 8.1: Proximity effects.

	Response Proximity				Stimulus Proximity	
	Both Hands		One Hand		Both hands	One hand
	Comp.	Incomp.	Comp.	Incomp.	Incomp.	Incomp.
RT to response adjacent to Repetition response	502	655	613	703	671	689
RT to Repetition response	475	596	594	613	596	594
Difference	27	59*	19	90**	75**	95*

* Significant p < .05
** " p < .01

The results for the CI condition are similar to those for the 2000 msec. data insofar as there is a significant difference between the REP Inner and Outer responses but are like the 1 msec. data in that there is no significant difference between SHNR Inner and Outer responses, and there also appears to be a proximity effect.

Incompatibe conditions

For these, in contrast to the compatible conditions, the Outer responses tend to be longer than the Inner. However, the only significant differences for the II condition were, for both the REP and OH RTs, between little and each of the other fingers, and for SHNR, between the little and each of the two Inner fingers. For the CI condition there were no significant differences between Outer and Inner responses for either the REP, SHNR or OH conditions. Welford (1971) also found, using an incompatible arrangement similar to that used in this experiment, that Outer responses especially by the little finger tended to be slower than Inner. These results were taken by Welford to indicate that the difference between Inner and Outer responses was not due purely to response factors, since it is evident, considering both compatible and incompatible conditions that it is responses to Inner stimuli which are longer than responses to Outer stimuli and not Inner responses per se which are slower than Outer.

In the compatible conditions, repetition effects, particularly the differences between SHNR and OH responses, tended to be greater for Inner fingers than for Outer. By contrast, in the incompatible conditions, they appear to be more nearly equal, and differences between REP and SHNR appear to be a little greater than between SHNR and OH.

In the II condition, the difference between REP and SHNR and SHNR and OH RTs was significant for each finger individually. In the CI condition, there were significant differences for Outer responses between REP and SHNR and SHNR and OH but only between REP and SHNR for Inner.

There does not appear to be a proximity effect in the incompatible conditions insofar as REP RTs are generally faster than all others including all those which constitute the SHNR mean RTs. However, to test for proximity effects, it is clear that one could compare the REP RTs with either (i) the mean RT to all responses immediately adjacent to the last response, in which case not every stimulus would be adjacent to the last stimulus, or (ii) the mean RT to all responses to stimuli that are immediately adjacent to the last stimulus in which case not every response would be adjacent to the last response. Both these comparisons were tested and the mean RTs and differences are shown in the second, fourth, fifth and sixth columns of Table 8.1. Using related samples t tests there were significant differences in each case for both the incompatible conditions.

DISCUSSION

If the proximity effect in the compatible arrangement was due to the fact that activation of the last response has some facilitating effect on adjacent responses, a proximity effect might be expected on this explanation to occur in the response proximity data for the incompatible conditions, but this was not found. Similarly, if it were due to the fact that stimulus identification is facilitated by the new stimulus being adjacent to the last, a proximity effect might be expected for the stimulus proximity data in the incompatible conditions, but again this was not found. The repetition effect in the incompatible condition seems therefore to be due largely to some saving in a central translation activity which is required for all non-repetition responses, including those adjacent to the last response and also those to stimuli adjacent to the last stimulus. The prediction that in the II condition S will be able to bypass the S-R code only for REP responses, so that the repetition effect would be in large part due to the difference between REP and SHNR responses for both Inner and Outer stimuli, seems to be supported by both the graphs and the statistical analyses.

The results of the CI condition appear to be more in agreement with those predicted than are those of the other two conditions. Most of the repetition effect with the compatible arrangement is due to the difference between Inner SHNR and Inner OH and most of the repetition effect with the incompatible arrangement is due to the difference between REP and SHNR for both Inner and Outer responses. Compared with the other two conditions, there might have been some interference with OH responses since in making these the S has to use a different S-R code from that used for the last response. Hence one might expect greater difference between OH and SHNR responses than in the other two conditions. However, the graphs give no indication that this has occurred.

Finally, it might be expected that the overall mean RT for the CI condition might lie midway between those for the CC and II. The graphs, however, indicate that it is approximately the same as that for the II. The difference between the CC and II conditions could be due to the extra time taken by the translation activity in the latter, plus perhaps some increased time spent in checking that the response made is in fact the correct one to the stimulus presented. For the one CI condition, there is the extra time due to the translation process for the incompatible arrangement but one might also expect some increased time over that for the CC condition in checking the accuracy of the response, since the S also has to check that he has used the correct S-R code as well as that he has arrived at the correct outcome once he has used it.

In summary, the results of the present experiment seem to be largely in agreement with the explanation of sequential effects in 8-choice tasks considered for the previous experiment.

CHAPTER IX.

AN EXAMINATION OF THE SEQUENTIAL EFFECTS IN AN 8-CHOICE SERIAL REACTION TIME TASK IN WHICH SUBJECTS ARE INSTRUCTED TO PREPARE FOR A PARTICULAR STIMULUS OR STIMULI

9.1. Experiment 10.

In the preceding two chapters using 8-choice tasks it was argued that an explanation of the data in terms of sequential processing strategies was unlikely to be correct since it would be predicted that if Ss checked, for example, REP stimuli, then SHNR and then OH, there should be significant differences between these for all fingers. The results so far have shown these to occur in more cases for Inner stimuli than for Outer. In addition, while the role of expectation and preparation on the part of the S was emphasized in explaining the 2-choice results, this has not been considered to be important in explaining the 8-choice. As mentioned previously this seems reasonable in view of the fact that any stimulus has only a .125 chance of occurring in the 8-choice situation while it has a .5 chance in the 2-choice situation.

One way in which both the above explanation in terms of sequential processing strategies and the role of expectation and preparation might be investigated in an 8-choice task would be to ask the S to prepare for either:

(1) a repetition of the last stimulus (REP),

(2) stimuli for the same hand as that involved in the last response (SH), and

(3) stimuli for the hand other than that involved in the last response (OH).

It might be expected on the above prediction that if instructions (1) and (2) call for sequential strategies similar to those that Ss might be assumed to adopt to produce a repetition effect, preparing for SH stimuli should make all SH RTs faster than all OH RTs even for Outer stimuli. Within SH and OH stimuli, patterns similar to those found previously in conditions without instructions for preparations should occur if Ss use, as has been assumed previously, reference points in order to locate stimuli in the display. Preparing for REP stimuli might be expected to make responses to these faster than to either SHNR or OH stimuli for both Inner and Outer responses since it seems reasonable that, as was hypothesised to explain in part the 2-choice results, any shortening of RT to a stimulus for which preparation has been made should be balanced in lengthening of the RT to other stimuli for which preparation has not been made. The proximity effect found previously for a compatible arrangement with no specific preparation was assumed to be due to a facilitation of stimulus and hence response identification. Thus if Ss prepare for the REP response, a proximity effect would not be predicted unless there also was some facilitation of the adjacent response.

In the 2-choice experiment in which Ss were asked to prepare for either repetitions or alternations, it was found that while all Ss were able to obey instructions to make repetition responses faster than alternation responses, and also to make alternation responses faster than repetition with an ISI of 2000 msec., only two out of six were able to do the latter with an ISI of 1 msec. It might be predicted that something similar should happen in the 8-choice situation. Preparing for either SH or REP stimuli should make responses to these faster than OH responses, but Ss might only be able to make responses to OH stimuli faster than those to SH if the ISI is long enough.

METHOD

Subjects. The Ss were 3 male and 3 female volunteers from the Psychology I course at the University of Adelaide. They were naive as to the aims of the experiment and their ages ranged from 17 to 25 years.

Apparatus. The apparatus and stimulus sequences were the same as for the previous two 8-choice experiments. Two ISIs were used, 2000 and 1 msec.

Procedure. The Ss attended on two consecutive days. Three Ss completed the conditions for the 1 msec. ISI on the first day and the 2000 msec. condition on the second, the other three completed the same conditions for the ISIs in reverse order. At each session, after being informed of the ISI, each S first completed one sequence in which he was simply instructed to respond as fast as possible to whichever stimulus came on, keeping his errors down to less than 5%. Then followed three conditions, in which the S was instructed to concentrate on either the same stimulus as last appeared, the stimuli belonging to the same hand as that involved in the last response, or the stimuli belonging to the other hand. One of the six Ss was assigned to each of the six possible orders of the three different instructions. There was a rest period of 2 minutes between each condition. Errors amounted to approximately 3.7%. These and all RTs less than 100 msecs. were omitted from the analyses.

RESULTS AND DISCUSSION

The 8 x 8 matrices for each condition are given in Appendix 9.4.

Figures 9.1, 9.2, 9.3 and 9.4 show, in the same manner as Fig.7.1, the mean RTs for the response for each finger for both hands combined when:

(1) it is a repetition (REP), that is, it follows itself,

(2) it follows a response by a finger of the same hand but is not a repetition (SHNR), and

(3) it follows a response by a finger of the other hand (OH).

The RTs which constitute each mean RT are indicated by letters each of which represents a previous response either of the same hand or the other hand.

Duncan multiple comparison analyses were used to test the significances of differences. To reduce the number of comparisons to a manageable size, the RTs for the individual fingers were combined into Inner and Outer mean RTs for REP, SHNR and OH responses separately. From the figures this seems to be justified since the patterns of RTs for index

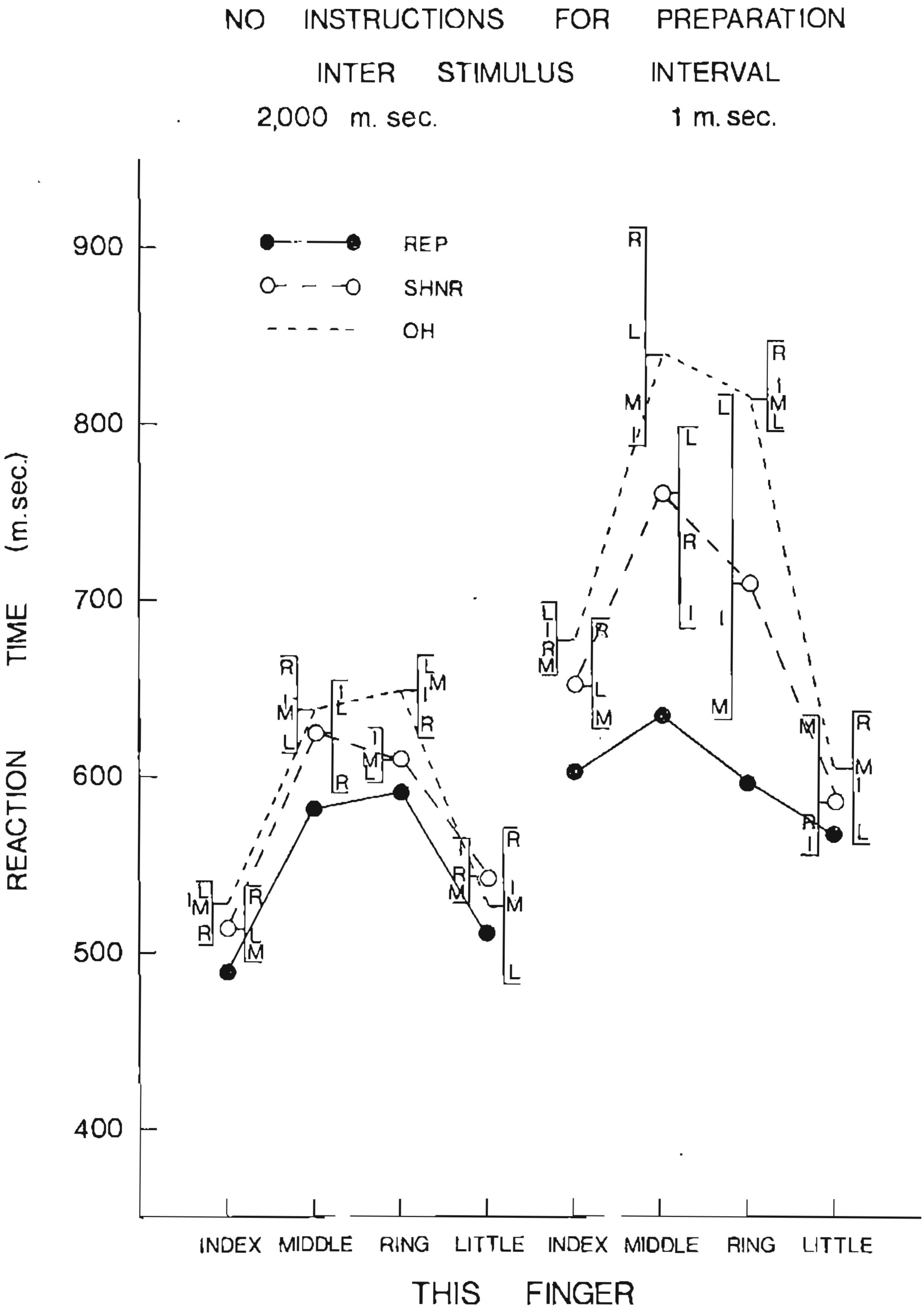

Fig. 9,1 Data (similar to that set out in Fig. 7,1) for the two interstimulus interval conditions without instructions for preparation.

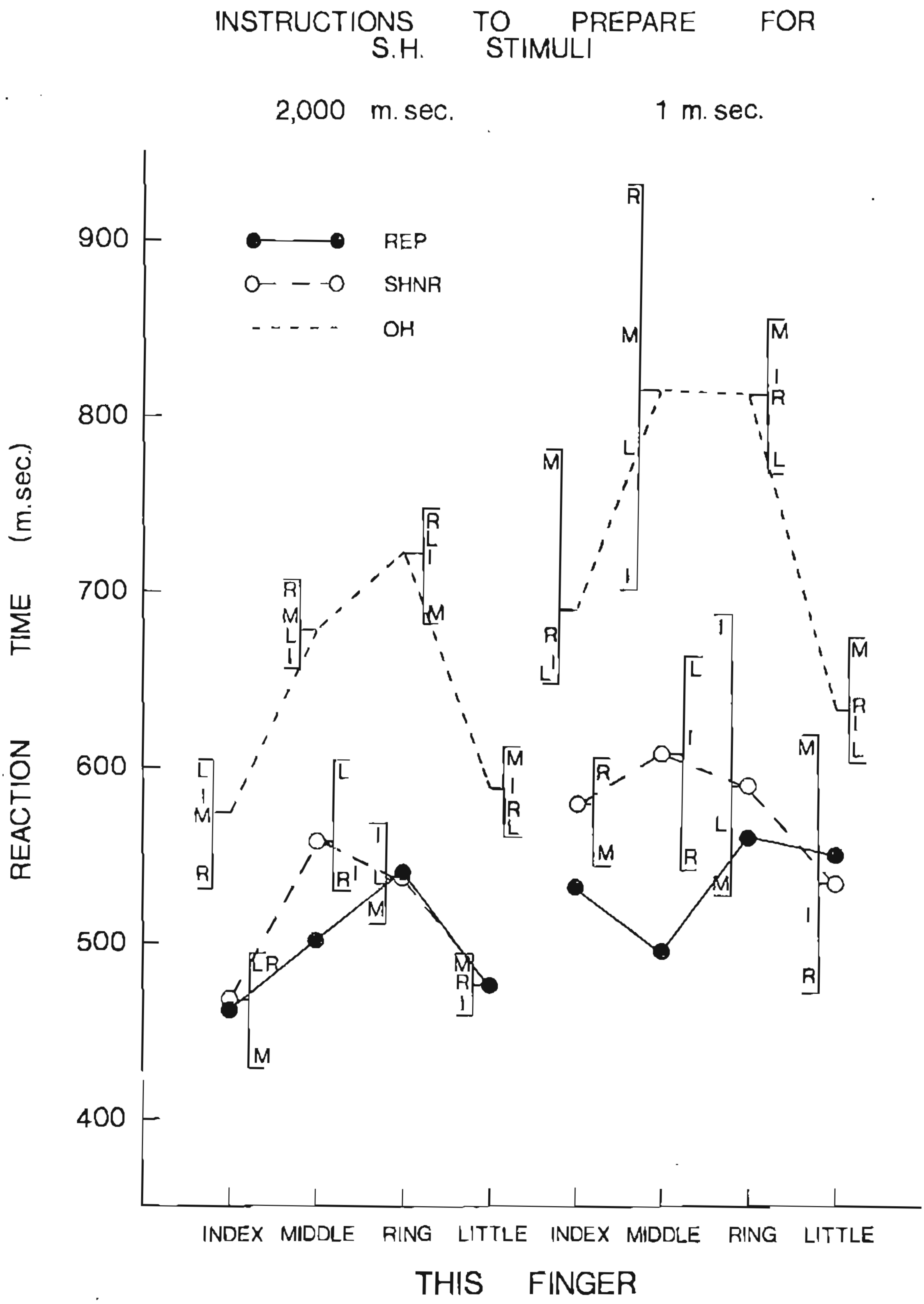

Fig. 9.2 Data (similar to that set out in Fig. 7.1) for the two interstimulus interval conditions with instructions to prepare for stimuli for the same hand (SH) as that involved in the last response.

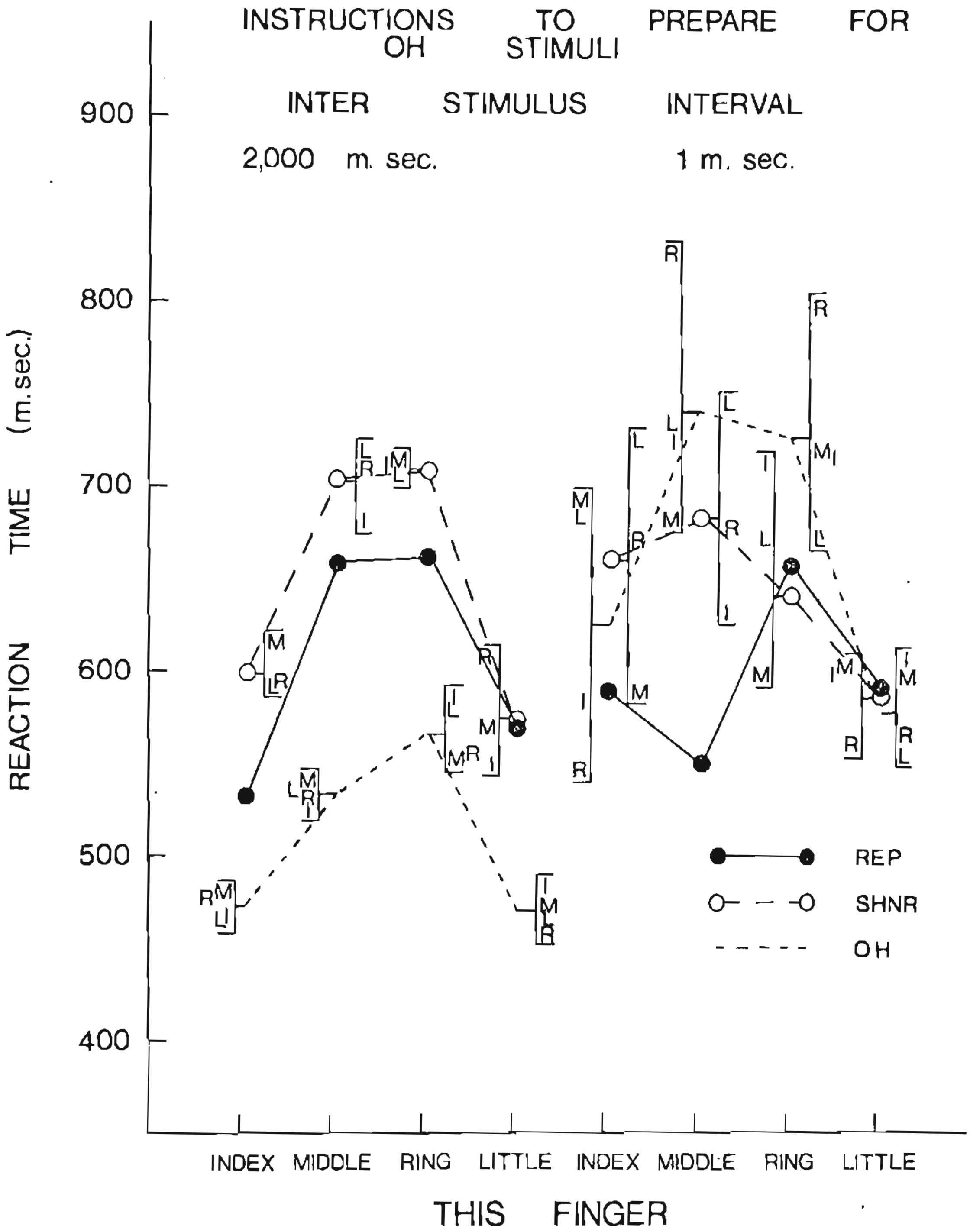

Fig. 9.3 Data (similar to that set out in Fig. 7.1) for the two interstimulus interval conditions with instructions to prepare for stimuli for the other hand (OH) to that involved in the last response.

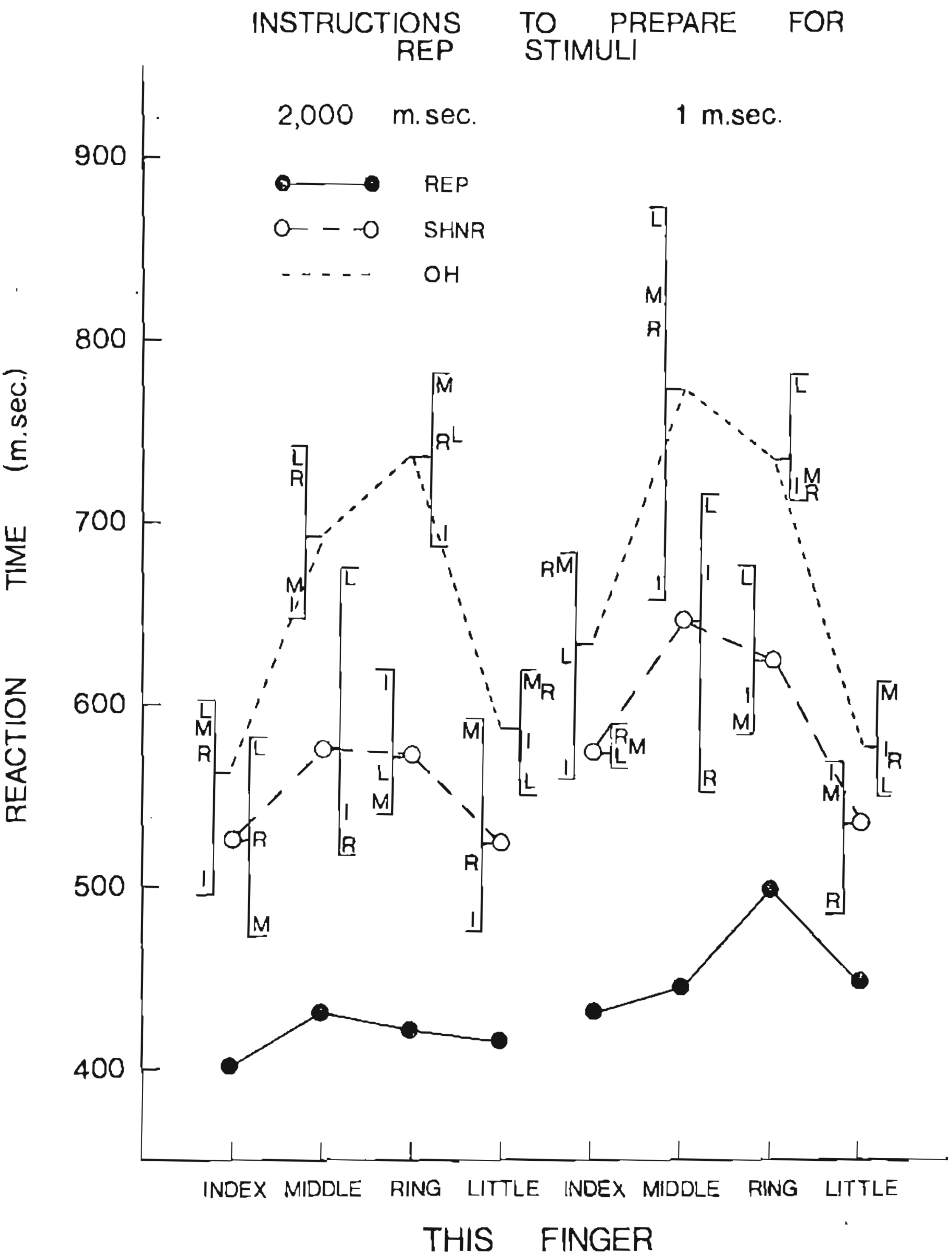

Fig. 9.4 Data (similar to that set out in Fig. 7.1) for the two interstimulus interval conditions with instructions to prepare for a repetition of the last stimulus (REP).

and little finger responses seem quite similar, as do those for middle and ring fingers. Thus each Duncan analysis compared, for one set of instructions, REP, SHNR and OH Inner and Outer RTs for each ISI. The full results are given in Appendix 9.3. Any difference referred to as significant will be with at least $p < .05$.

To test for possible proximity effects, the mean RTs for all REP responses were compared with the mean RT for all responses immediately adjacent to the last response for each of the different instruction conditions. These means and their differences are shown in Table 9.1. The differences were tested by related samples t tests.

Table 9.1: Proximity effects.

	2000 msec.				1 msec.			
	PREPARATION							
	None	Same hand	Other hand	Same stimulus	None	Same hand	Other hand	Same stimulus
RT to response adjacent to repetition response	575	517	641	531	691	560	614	588
RT to repetition response	528	494	605	414	603	532	598	457
Difference	47	23	36	117**	88	28	16	131**

**Significant $p < .01$

Conditions without Instructions for Preparation

The pattern of RTs shown in Figure 9.1 is similar to that found in Experiment 8 for both the 1 msec. and 2000 msec. ISIs. In the 2000 msec. condition, the repetition effects are not very large. The only significant difference between REP and SHNR and SHNR and OH responses was that between REP and SHNR Outer responses. This is in contrast to the same comparisons in the 2000 msec. condition of Experiment 8 but the fact that the same Ss were used for all conditions in the present experiment makes it possible that results were influenced by transfer from other conditions. The Inner responses for the REP, SHNR and OH conditions were all significantly longer than their Outer equivalents.

In the 1 msec. condition by contrast, there is no significant difference between Inner and Outer REP responses nor between Inner and Outer SHNR responses. Inner OH responses, however, were significantly greater than their Outer equivalents. The main repetition effect is again between Inner REP and Inner OH responses, the only significant differences being between these two responses. None of the differences between REP, SHNR or OH responses were significant for the Outer responses. As was found previously for SHNR RTs, the middle following L responses and also to some extent the ring following I responses tend to be longer than the other SHNR responses.

The differences in the proximity analyses were not significant with either ISI. The large difference for the

1 msec. condition seems to be partly due to the very long RT for the ring following L response which can be seen in Figure 9.1.

Conditions in which there was preparation for SH stimuli

The patterns of RTs are more nearly similar for the two ISI conditions. There are only small differences between SHNR and REP responses none of which were significant for either Inner or Outer RTs with either ISI, but quite substantial and significant differences for both Inner and Outer responses between SHNR and OH RTs for both ISIs.

Inner responses again seem slower than the Outer. For the 1 msec. condition, there was a significant difference between Inner and Outer stimuli only for OH responses while for the 2000 msec. condition, there were significant differences for SHNR and OH responses but not for REP responses.

The fact that when Ss were instructed to prepare for SH stimuli, RTs to these were markedly faster than OH RTs for Outer stimuli as well as Inner would seem to argue against the S checking sequentially in an order such as REP, then SHNR and then OH, when he is not given specific instructions of this kind.

The proximity analyses showed no significant differences for either ISI condition.

Conditions in which there was preparation for OH stimuli

Here, by contrast with the conditions in which Ss prepared for SH stimuli, the two ISI conditions are quite different. With an ISI of 2000 msec., both Inner and Outer

OH responses are clearly faster than their SHNR and REP equivalents, but this is not so with the 1 msec. ISI. With the 2000 msec. ISI, of the differences between REP, SHNR and OH responses, only those between REP and SHNR Inner, and between REP and OH and SHNR and OH for both Inner and Outer, were significant. With the 1 msec. ISI, none of the differences between REP and SHNR, and SHNR and OH responses were significant for either Inner or Outer stimuli.

Once again Inner responses seem on average slower than Outer, all the differences whether for REP, SHNR or OH between Inner and Outer responses being significant with the 2000 msec. ISI, but only between OH Inner and Outer with the 1 msec.

One hypothesis to be tested by this experiment was the ability of the S to shift his attention from the last stimulus or from the stimuli for the hand involved in the last response to those for the other hand. The assumption was that while, given an ISI of 2000 msec., Ss would be able to shift their attention and prepare for OH stimuli, they would not be able to do this as well given an ISI of 1 msec. The results support the hypothesis insofar as Ss made OH responses faster than SH with a 2000 msec. ISI but not with a 1 msec.

It may be noted that in the 2000 msec. condition in which Ss prepared for OH stimuli, REP responses were still faster than SHNR. This may well be due to the S still after checking the OH stimuli, tending to use the last stimulus as a reference point. With the 1 msec. ISI, instructions to prepare for OH stimuli made little difference to the RTs to to Outer stimuli, compared with no specific instructions. The main difference was in the apparent decrease in RT for Inner OH and SHNR responses. Thus it would appear that, with a 1 msec. ISI, S is able to attend to OH stimuli to some extent but perhaps not enough to prepare responses as fully as when the ISI is longer.

Conditions in which there was preparation for the REP stimulus

Results are similar with both ISIs, Outer as well as Inner REP RTs seem much faster than their SHNR and OH equivalents. With both ISIs, the differences between REP and SHNR and SHNR and OH responses were significant for the Inner responses. Both were also significant for Outer responses with the 2000 msec. ISI, but only that between REP and SHNR was significant with the 1 msec. Outer responses were again significantly faster than Inner for the OH and SHNR stimuli with both ISIs, but RTs to Outer and Inner REP stimuli did not differ significantly with either ISI.

It can be seen in Figure 9.4 that for both ISIs, REP responses are faster than all other responses, indicating that there are no proximity effects. These observations are supported by the results of the proximity analyses, the differences shown in the fourth and eighth columns of Table 9.1, both being significant. Since, when instructed to prepare for the last stimulus, the S is able to prepare for a specific response, much of the advantage of REP RTs could be due to specific motor preparation. The fact that there are significant differences between REP RTs and those for responses immediately adjacent to the last response, would tend to support this since, if the advantage of REP responses were simply due to attention, adjacent responses might also be expected to benefit.

In summary then, the results seem not to favour an explanation of sequential effects in terms of a simple sequential processing strategy such as checking REP or SH stimuli first before OH since when Ss are instructed to do this, results somewhat different from those found under conditions of no specific instructions are obtained. Nevertheless, the results also indicate that attention and preparation can be important factors in determining the kinds of sequential effects obtained and that Ss are able to adopt different sequential strategies given the appropriate instructions and time in which to do so.

CHAPTER X.

SUMMARY AND CONCLUSIONS

10.1. Summary of results

In Chapter II the importance of higher order effects in formulating an adequate explanation of sequential effects in serial RT tasks was emphasised. Both the models proposed by Bertelson (1963) for the repetition effect and that by Williams (1966) for the alternation effect assumed that basically the effects were due to the immediately preceding stimulus. Remington (1969), however, had shown the existence of higher order effects for the repetition effect, implying that Bertelson's model was inadequate. It therefore seemed useful to analyse in the same way the data from an experiment producing an alternation effect to see whether, in formulating an explanation of that also, higher order effects needed to be taken into account.

The results of Experiment 1 showed that there were in fact higher order alternation effects, and that Williams' proposed explanation for the alternation effect was therefore inadequate. They also showed that higher order repetition effects could occur along with an alternation effect. These results and those of Remington (1969) suggested an explanation of sequential effects in terms of expectation and preparation on the part of the S. The progressive decrease in RT as the sequence increased in length and progressive increase in RT with length of sequence prior to discontinuation, suggested that preparation for one stimulus led to a decrease in RT to it if it occurred, but at the expense of increased RT if the other event occurred.

However, the fact left unexplained was that some experiments have shown first order repetition effects and some first order alternation effects. It was mentioned in Chapter I that there was still some uncertainty as to whether the repetition effect decreased and changed to an alternation effect with an increase in ISI. Experiment 2 did not show a decrease in the repetition effect with increasing ISI, but did show a change from a repetition to an alternation effect. The number of trials was found to be important in obtaining the change, and this factor was offered as at least a partial explanation of the discrepant results in the literature, particularly the results of Schvaneveldt & Chase (1969).

In addition, it was found in Experiment 2 that the higher order repetition effects at low ISIs were different in kind from those for the alternation effects and also from higher order repetition effects obtained at higher ISIs, in that there was no increase in the RT to the discontinuation of repetition sequences as the preceding sequence of repetitions increased in length. On the basis of this, it was suggested that the repetition effect and the alternation effect at high ISIs were due to subjective expectancy with the additional assumption that the Ss expected overall, more alternations than repetitions, in a manner analogous to the gamblers fallacy phenomenon, but that at low ISIs the repetition effect was due to some automatic facilitation either of motor or coding. This facilitation could be a matter of either perception or response but previous work reviewed in Chapter II seems to favour the latter. Thus, subjective expectancy and preparation on the one hand and some kind of motor or coding facilitation on the other were both seen to be required for an adequate explanation of sequential effects in 2-choice tasks.

The success of the higher order analyses in the first two experiments suggested that it might be revealing to use it to examine the effects of other variables such as a comparison between a compatible and incompatible S-R arrangement. This was carried out in Experiment 3. On the basis of the above explanation it was predicted that, in addition to there being a larger repetition effect at the low ISI for the incompatible arrangement, there would also be less higher order effects at both a low and high ISI, since the complexity of the S-R code would make anticipation and preparation more difficult. The exception to this would be the higher order repetition effects in the low ISI condition which would still be expected to occur.

A larger repetition effect and higher order repetition effects were found at the low ISI and in this condition there were also smaller higher order alternation effects than in the corresponding compatible condition. At the higher ISI there did seem to be some lessening in the higher order effects with the incompatible arrangement but these still occurred, suggesting that the Ss are still able to anticipate and prepare for a repetition or alternation sequence. There also seemed to be some increase in the higher order repetition effects. These appeared to be similar to the repetition effects obtained at the low ISI insofar as RT decreased as the length of the repetition sequence increased, but varied little to discontinuation of repetition sequences of different length. This, as suggested, may have been due to some facilitation of coding rather than of response, since the latter would also have been expected in the 1 sec. compatible S-R condition.

Little difference in the sequential effects was found across the massed trials of Experiment 4 except that greater variability in the effects seemed to occur with a 50 msec. ISI - that is where first order repetition effects had been found previously. This, it was suggested, might be due to interaction of the motor or coding facilitation with the S's attempt to prepare for more alternations than repetitions.

An explanation in terms of guessing strategies involving anticipation and preparation was further investigated by asking Ss to try to prepare for either repetitions or alternation at two different ISIs. Ss were found in Experiment 5 to be able to do both equally well at the high ISI but some found difficulty in making alternation RTs faster than repetition RTs at the low ISI. This result was taken as evidence that both preparation and motor or coding facilitation effects are required to explain results at low ISIs where first order repetition effects have usually been found. It was also regarded as supporting the view that expectation and preparation was sufficient alone to explain the results for higher ISIs.

Remington (1969) found a repetition effect using an ISI of 4 sec. whereas the experiments in this thesis and those previously reported in the literature have usually found alternation effects using ISIs of greater than 1 sec. In order to test the possibility that the differences in results were due to different instructions given to Ss concerning the nature of the stimulus sequence, Ss were instructed in Experiment 6 in such a way as to expect either more repetitions, more alternations, or the same number of each, although in every case equal numbers of each were given. The results, while showing a slight effect, were not sufficient to explain the difference between the findings of Experiment 1 and that of Remington.

As a further test of the explanation of sequential effects suggested above, the effects of different probabilities of repetitions and alternations were investigated in Experiment 7. Sequences were constructed in such a way that the probabilities of repetitions and alternations differed in the first two-thirds, but were the same in the last one-third. It was hypothesised that if Ss did anticipate and prepare for sequences of repetitions and alternations, this anticipation would be biassed in favour of the predominant event, whether repetition or alternation, during the first two-thirds of the sequence, and would continue to some extent in the last one-third even though the objective probabilities were equal. The results supported the hypothesis, and were consistent with the proposed explanation for sequential effects.

In Chapter II it was suggested that since a detailed analysis had been important in understanding the nature of sequential effects in a 2-choice task, there was a need for similar detailed treatment of tasks involving more than two choices. The analysis of Remington (1971) for a 4-choice task was mentioned as an example of this. Accordingly an analysis was developed for an 8-choice task which would allow a comparison of the RT for each stimulus following every other stimulus. This was not a higher order analysis, insofar as only the effects of stimuli one back in the sequence were examined, it being thought that if more than this were attempted, there would be too many combinations to consider. The results of Experiment 8 indicated that:

(1) not all responses seem to benefit from a repetition of the previous stimulus,

(2) repeated responses are not the only ones to benefit from a repetition of the previous stimulus: responses immediately adjacent to the last response also benefit, and

(3) both these effects, but more particularly the latter, seem to depend upon the ISI, being greater the shorter the ISI.

These results imply that certain modifications are required to the explanation in terms of sequential processing strategies put forward by Welford (1970). The fact that repetition effects seem to exist for Inner (i.e. middle and ring) fingers and to a lesser extent or not at all for Outer (i.e. little and index) fingers raises difficulties for any simple explanation in terms of sequential processing such as assuming that Ss first inspect the position of the previous stimulus, then those relating to the same hand, and only afterwards those relating to the other hand, since this would imply that all repeated responses, both Outer as well as Inner, should be faster by the same amount than those to stimuli relating to other fingers on the same hand, and all these latter equally faster than those for stimuli relating to corresponding fingers on the other hand.

An alternative explanation was proposed in which it was assumed that Ss locate the correct stimulus by first attending or orientating to the stimulus, and then identifying it by seeking the nearest of four reference points:

(1) the two ends of the display,

(2) the midline of the display (which might be real or imaginary), and

(3) the position of the last stimulus.

Outer stimuli would thus be located quickly regardless of the position of the last stimulus, while Inner stimuli would have to be identified as next to an Outer stimulus and so taking longer. In addition, if it is assumed that the ends of the display act as better reference points than the midline (which has a stimulus light on either side of it), the slightly longer RTs for the index finger than for the little finger would be explained. The exception to the above would be in the case of a repeated stimulus, or if the ISI was short enough a stimulus adjacent to the last stimulus, both of which would then be identified quickly. Inner stimuli would thus benefit most from a repetition of the last stimulus. The fact that these effects were found to depend on ISI suggests that while the ends and middle of the display might be thought of as permanent reference points, the position of the last stimulus seems to act as a temporary reference point only, as it would if it was a function of a memory trace of the last stimulus which decays with time in the manner proposed by Bertelson (1963) for the 2-choice situation.

The above explanation assumes that the repetition effect in an 8-choice task is basically due to a stimulus identification facilitation in contrast to the response facilitation plus subjective expectancy suggested to explain the same effect in the 2-choice situation.

This explanation was further investigated in Experiment 9 by using the same detailed analysis in a comparison of a compatible with an incompatible S-R relationship in an 8-choice task. Using an ISI close to that for the low ISI condition for the first 8-choice experiment, a proximity effect was found with the compatible arrangement but not with the incompatible. This result, and the generally greater difference between repetition RTs and the RTs to other stimuli belonging to the same hand for the incompatible as compared with the compatible condition, were explained in terms of the above assumptions by noting that first, an adjacent stimulus does not necessarily mean an adjacent response, and second that an incompatible arrangement would mean that the responses for all nonrepetitions would have to be selected with the use of the S-R code. Only for repetition responses could the code be bypassed. Thus the repetition effect here was assumed to be mainly due to a central coding facilitation linking stimulus to response.

The role of attention and preparation was investigated in Experiment 10 by asking Ss to prepare for either repetitions of the last stimulus, or stimuli for the same hand as that involved in the last response, or for stimuli for the other hand. It was found that Ss were able to make RTs for responses of the other hand faster than repetition responses with a long (2000 msec.) but not with a short (1 msec.) ISI. In all other conditions Ss were able to make responses to REP or SH stimuli faster than those to the remaining stimuli as instructed. These results indicated that Ss are able to adopt different sequential strategies given the appropriate instructions and time in which to do so. However, the differences between the overall patterns of RTs for these conditions with specific instructions and those in which no such instructions were given, suggested that none of these strategies is the same as that which Ss use without specific instructions.

10.2. Conclusions

It was argued in Chapter II that the sequential effects in serial RT tasks may have different causes depending on the experimental conditions. This view would seem to be supported by the results of the experiments reported in this thesis.

Different strategies seem to be used for 2- and 8-choice situations. In the 2-choice task, Ss seem to anticipate sequences of repetitions and alternations. In the 8-choice; the S seems to identify the correct stimulus by means of reference points after the stimulus has been presented, the last stimulus acting temporarily as one of these reference points. On this explanation the S would seem in the 8-choice situation to adopt a more passive role. Thus higher order effects might be predicted to be much less than in the 2-choice situation. One simple way of testing this prediction might be to collapse the 8-choice data into responses for the left and right hands and examine it with the higher order analysis used for the 2-choice data. The explanation could also be further investigated by a study of eyemovements in an 8-choice task.

Both the abovementioned strategies, however, may change depending on other factors such as ISI, stimulus-response code, probability of repetitions and alternations and instructions.

As the ISI decreases in the 2-choice task, a motor or coding facilitation seems to compete with the S's overall anticipation of more alternations. In the 8-choice task, as the ISI decreases, Ss seem more able to use the position of the last stimulus not only as a reference point facilitating a response to a repetition of that stimulus but also as a guide to the location of the adjacent stimulus should it occur. This explanation assumes that the use of the last stimulus as a reference point depends on a memory trace which decays with time. The fact that a memory trace which decays with time is assumed in the 8-choice case implies that such a trace must also exist in the 2-choice. However, the results suggest that in the 2-choice situation it does not determine the sequential effects except as a basis for anticipation of the next stimulus.

As the S-R code becomes incompatible the Ss are unable to use the 8-choice strategy to produce a proximity effect and the repetition effects seem to be largely due to a central coding facilitation. In the 2-choice situation an incompatible S-R code would seem to make the Ss' anticipation of stimuli more difficult particularly at low ISIs, tending to reduce the higher order alternation effects. In this case as in the 8-choice compatible task both of which changes can be seen as increasing the difficulty of the task from a compatible 2-choice, the S would seem to become more passive with less anticipation.

If the probability of repetitions and alternations is changed in the 2-choice task, Ss seem capable of altering their expectation and preparation in favour of the predominant event. While changes in stimulus probability were not investigated using the 8-choice task, it seems likely that Ss might also be able to change their strategy in a similar way, perhaps tending to adopt sequential processing beginning by anticipating the most probable event. Some evidence for this is contained in the results of the experiment with a 4-choice task reported by Remington (1971).

The S also seems to be capable of adopting different strategies depending on instructions although other factors such as ISI are important.

In summary, the results of the experiments reported in this thesis have shown:

(1) that sequential effects may be due to stimulus, response or central factors and may involve memory and subjective expectancy and preparation depending on the experimental situation, and

(2) the flexibility of which the S is capable in dealing with the tasks.

Much of the work of this thesis has consisted of elucidating those types of strategies which Ss can, and those which they do in fact seem to adopt under different experimental conditions.

APPENDIX - TABLE OF CONTENTS

APPENDIX 4.1

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 1.

(i) Difference between reaction times for AA and BA (msec)

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	15343	5	3068.6			
2 (interstimulus interval)	29.556	2	14.778	2/1x2	<1	
3 (number of runs)	354.69	1	354.69	3/1x3	26.68	<.005
1x2	991.78	10	99.178			
1x3	66.472	5	13.294			
2x3	206.89	2	103.44	2x3/1x2x3	<1	
1x2x3	1388.4	10	138.84			
TOTAL	18381	35				

(ii) Higher order <u>alternation</u> analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1830.9	5	366.17			
2 (differences between sequence lengths)	1161.8	2	580.89	2/1x2	2.086	n.s.
3 (difference between the differences)	2737.8	1	2737.8	3/1x3	200.4	<.005
4 (interstimulus interval)	370.48	2	185.24	4/1x4	2.715	n.s.
5 (number of runs)	65.560	1	65.560	5/1x5	<1	
1x2	2784.2	10	278.42			
1x3	68.301	5	13.660			
1x4	682.19	10	68.219			
1x5	955.75	5	191.15			
2x3	280.84	2	140.42	2x3/1x2x3	<1	
2x4	807.71	4	201.93	2x4/1x2x4	1.576	n.s.
2x5	363.34	2	181.67	2x5/1x2x5	<1	
3x4	986.26	2	493.13	3x4/1x3x4	9.802	<.005
3x5	70.042	1	70.042	3x5/1x3x5	<1	
4x5	110.26	2	55.130	4x5/1x4x5	<1	
1x2x3	5465.2	10	546.52			
1x2x4	2563.1	20	128.16			
1x2x5	1921.4	10	192.14			
1x3x4	503.07	10	50.307			
1x3x5	395.71	5	79.142			
1x4x5	1003.5	10	100.35			
2x3x4	1001.2	4	250.29	2x3x4/ 1x2x3x4	1.372	n.s.
2x3x5	415.58	2	207.79	2x3x5/ 1x2x3x5	1.294	n.s.
2x4x5	367.38	4	91.845	2x4x5/ 1x2x4x5	<1	
3x4x5	44.333	2	22.167	3x4x5/ 1x3x4x5	<1	
1x2x3x4	3647.7	20	182.38			
1x2x3x5	1605.4	10	160.54			
1x2x4x5	3979.0	20	198.95			
1x3x4x5	1586.3	10	158.63			
2x3x4x5	478.08	4	119.52	2x3x4x5/ 1x2x3x4x5	<1	
1x2x3x4x5	2542.7	20	127.14			
TOTAL	40795	215				

(iii) Higher order <u>repetition</u> analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	672.04	5	134.41			
2 (differences between sequence lengths)	419.01	2	209.50	2/1x2	<1	
3 (difference between the differences)	3683.6	1	3683.6	3/1x3	17.05	<.025
4 (interstimulus interval)	241.01	2	120.50	4/1x4	1.162	n.s.
5 (number of runs)	32.667	1	32.667	5/1x5	<1	
1x2	7549.9	10	754.99			
1x3	1080.0	5	216.01			
1x4	1037.0	10	103.70			
1x5	284.22	5	56.844			
2x3	244.23	2	122.12	2x3/1x2x3	<1	
2x4	439.66	4	109.91	2x4/1x2x4	<1	
2x5	2506.9	2	1253.4	2x5/1x2x5	3.426	n.s.
3x4	525.56	2	262.78	3x4/1x3x4	2.108	n.s.
3x5	80.667	1	80.667	3x5/1x3x5	<1	
4x5	29.528	2	14.764	4x5/1x4x5	<1	
1x2x3	3182.4	10	318.24			
1x2x4	10199	20	509.93			
1x2x5	3658.6	10	365.86			
1x3x4	1246.6	10	124.66			
1x3x5	1054.0	5	210.80			
1x4x5	701.75	10	70.175			
2x3x4	1155.0	4	288.75	2x3x4/ 1x2x3x4	<1	
2x3x5	333.08	2	166.54	2x3x5/ 1x2x3x5	<1	
2x4x5	1050.0	4	262.51	2x4x5/ 1x2x4x5	<1	
3x4x5	257.86	2	128.93	3x4x5/ 1x3x4x5	<1	
1x2x3x4	7646.5	20	382.33			
1x2x3x5	5418.6	10	541.86			
1x2x4x5	6031.4	20	301.57			
1x3x4x5	1434.6	10	143.46			
2x3x4x5	855.81	4	213.95	2x3x4x5 1x2x3x4x5	<1	
1x2x3x4x5	9828.4	20	491.42			
TOTAL	72880	215				

APPENDIX 4.2

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 2.

(i) Difference between reaction times for AA and BA (msec)

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	3432.7	5	686.53			
2 (interstimulus interval)	11052	2	5526.1	2/1x2	11.07	<.005
3 (number of runs)	729.00	1	729.00	3/1x3	1.72	n.s.
1x2	4992.2	10	499.22			
1x3	2118.3	5	423.67			
2x3	756.17	2	378.08	2x3/1x2x3	1.08	n.s.
1x2x3	3497.5	10	349.75			
TOTAL	26578	35				

(ii) Difference between reaction times for AA and BA (msec) for the first three runs.

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	3378.3	5	675.66			
2 (interstimulus interval)	2992.4	2	1496.2	2/1x2	2.15	n.s.
1x2	6966.9	10	696.69			
TOTAL	13338	17				

(iii) Mean reaction time (msec)

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	19382	5	3876.3			
2 (interstimulus interval)	18749	2	9374.7	2/1x2	12.01	<.005
3 (number of runs)	256.00	1	256.00	3/1x3	<1	
1x2	7808.3	10	780.83			
1x3	2451.3	5	490.27			
2x3	283.50	2	141.75	2x3/1x2x3	<1	
1x2x3	2420.2	10	242.02			
TOTAL	51350	35				

(iv) Higher order <u>alternation</u> analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	2285.3	5	457.05			
2 (differences between sequence lengths)	777.56	2	388.78	2/1x2	1.92	n.s.
3 (difference between the differences)	14211	1	14211	3/1x3	38.73	<.005
4 (interstimulus interval)	366.04	2	183.02	4/1x4	<1	
5 (number of runs)	35.852	1	35.852	5/1x5	<1	
1x2	2026.7	10	202.67			
1x3	1834.6	5	366.92			
1x4	2455.5	10	245.55			
1x5	494.09	5	98.819			
2x3	1186.2	2	593.10	2x3/1x2x3	1.61	n.s.
2x4	1931.4	4	482.84	2x4/1x2x4	2.47	n.s.
2x5	496.29	2	248.14	2x5/1x2x5	1.80	n.s.
3x4	4187.4	2	2093.7	3x4/1x3x4	3.23	n.s.
3x5	2.2407	1	2.2407	3x5/1x3x5	<1	
4x5	169.93	2	84.963	4x5/1x4x5	2.92	n.s.
1x2x3	3672.7	10	367.27			
1x2x4	3903.6	20	195.18			
1x2x5	1375.9	10	137.59			
1x3x4	6485.1	10	648.51			
1x3x5	628.81	5	125.76			
1x4x5	290.63	10	29.063			
2x3x4	2001.7	4	500.42	2x3x4/ 1x2x3x4	1.87	n.s.
2x3x5	259.06	2	129.53	2x3x5/ 1x2x3x5	1.10	n.s.
2x4x5	1175.8	4	293.94	2x4x5/ 1x2x4x5	1.46	n.s.
3x4x5	222.93	2	111.46	3x4x5/ 1x3x4x5	<1	
1x2x3x4	5363.6	20	268.18			
1x2x3x5	1174.0	10	117.40			
1x2x4x5	4035.5	20	201,78			
1x3x4x5	1257.5	10	125.75			
2x3x4x5	100.27	4	25.067	2x3x4x5/ 1x2x3x4x5	<1	
1x2x3x4x5	3241.1	20	162.06			
TOTAL	67648	215				

(v) Higher order <u>repetition</u> analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1774.8	5	354.97			
2 (differences between sequence lengths)	825.36	2	412.68	2/1x2	2.49	n.s.
3 (difference between the differences)	5622.2	1	5622.2	3/1x3	23.84	<.005
4 (interstimulus interval)	3339.2	2	1669.6	4/1x4	8.82	<.01
5 (number of runs)	4.1667	1	4.1667	5/1x5	<1	
1x2	1660.6	10	166.06			
1x3	1179.0	5	235.81			
1x4	1892.9	10	189.29			
1x5	926.89	5	185.38			
2x3	3212.7	2	1606.3	2x3/1x2x3	5.13	<.05
2x4	1273.9	4	318.47	2x4/1x2x4	2.34	n.s.
2x5	281.86	2	140.93	2x5/1x2x5	2.25	n.s.
3x4	780.45	2	390.23	3x4/1x3x4	1.46	n.s.
3x5	1.1852	1	1.1852	3x5/1x3x5	<1	
4x5	59.083	2	29.542	4x5/1x4x5	<1	
1x2x3	3132.2	10	313.22			
1x2x4	2726.9	20	136.35			
1x2x5	625.25	10	62.525			
1x3x4	2667.6	10	266.76			
1x3x5	334.76	5	66.952			
1x4x5	1897.2	10	189.72			
2x3x4	2117.5	4	529.37	2x3x4/1x2x3x4	1.34	n.s.
2x3x5	186.73	2	93.366	2x3x5/1x2x3x5	<1	
2x4x5	832.72	4	208.18	2x4x5/1x2x4x5	<1	
3x4x5	13.731	2	6.8657	3x4x5/1x3x4x5	<1	
1x2x3x4	7885.8	20	394.29			
1x2x3x5	2898.2	10	289.82			
1x2x4x5	4333.3	20	216.67			
1x3x4x5	1180.7	10	118.07			
2x3x4x5	927.85	4	231.96	2x3x4x5/1x2x3x4x5	1.55	n.s.
1x2x3x4x5	2988.4	20	149.42			
TOTAL	57583	215				

APPENDIX 5.1

RELATED SAMPLES T TESTS FOR EXPERIMENT 3.

Comparing the difference between the compatible and incompatible stimulus - response conditions of:

(i) the overall mean reaction time (msec) for the 50 msec interstimulus interval condition;
$t = 2.78$, d.f. = 5, $P < .05$,

(ii) the difference between the reaction times for AA and BA (msec) for the 50 msec interstimulus interval condition;
$t = 2.90$, d.f. = 5, $P < .05$,

(iii) the overall mean reaction time (msec) for the 1000 msec interstimulus interval condition;
$t = 2.90$, d.f. = 5, $P < .05$,

(iv) the difference between the reaction times for AA and BA (msec) for the 1000 msec interstimulus interval condition;
$t = 0.49$, d.f. = 5, n.s.,

(v) the mean reaction time for AA (msec) for the 50 msec interstimulus interval condition;
$t = 1.75$, d.f. = 5, n.s.,

(vi) the mean reaction time for BA (msec) for the 50 msec interstimulus interval condition;
$t = 3.08$, d.f. = 5. $P < .05$,

(vii) the mean reaction time for AA (msec) for the 1000 msec interstimulus interval condition;
$t = 8.51$, d.f. = 5, $P < .001$,

(viii) the mean reaction time for BA (msec) for the 1000 msec interstimulus interval condition;
$t = 7.28$, d.f. = 5, $P < .001$.

APPENDIX 5.2

ANALYSIS OF VARIANCE SUMMARY TABLES
FOR EXPERIMENT 3.

(i) Higher order alternation analysis for the 50 msec interstimulus interval compatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1061.1	5	212.23			
2 (differences between sequence lengths)	1309.1	2	654.53	2/1x2	<1	
3 (differences between the differences)	4556.2	1	4556.2	3/1x3	20.06	<.01
1x2	1959.3	10	195.93			
1x3	1135.6	5	227.12			
2x3	516.50	2	258.25	2x3/1x2x3	1.08	n.s.
1x2x3	2391.2	10	239.12			
TOTAL	12929	35				

(ii) Higher order repetition analysis for the 50 msec interstimulus interval compatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	808.33	5	161.67			
2 (differences between sequence lengths)	1003.5	2	501.75	2/1x2	2.44	n.s.
3 (differences between the differences)	693.44	1	693.44	3/1x3	2.52	n.s.
1x2	2058.2	10	205.82			
1x3	1375.9	5	275.18			
2x3	334.06	2	167.03	2x3/1x2x3	<1	
1x2x3	2203.6	10	220.36			
TOTAL	8477.0	35				

(iii) Higher order alternation analysis for the 50 msec interstimulus interval incompatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	11361	5	2272.2			
2 (differences between sequence lengths)	11907	2	5953.7	2/1x2	19.79	< .005
3 (difference between the differences)	1764.0	1	1764.0	3/1x3	2.32	n.s.
1x2	3008.3	10	300.83			
1x3	3804.3	5	760.87			
2x3	5880.5	2	2940.2	2x3/1x2x3	5.33	< .05
1x2x3	5517.2	10	551.72			
TOTAL	43242	35				

(iv) Higher order repetition analysis for the 50 msec interstimulus interval incompatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1559.6	5	311.92			
2 (differences between sequence lengths)	16810	2	8405.1	2/1x2	9.63	< .005
3 (difference between the differences)	103.36	1	103.36	3/1x3	< 1	
1x2	8732.5	10	873.25			
1x3	862.47	5	172.49			
2x3	1723.4	2	861.69	2x3/1x2x3	1.69	n.s.
1x2x3	5101.3	10	510.13			
TOTAL	34893	35				

(v) Higher order alternation analysis for the 1000 msec interstimulus interval compatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	265.14	5	53.028			
2 (differences between sequence lengths)	221.72	2	110.86	2/1x2	3.49	n.s.
3 (difference between the differences)	2550.2	1	2550.2	3/1x3	18.02	<.01
1x2	317.28	10	31.728			
1x3	707.58	5	141.52			
2x3	376.17	2	188.08	2x3/1x2x3	3.91	n.s.
1x2x3	481.50	10	48.150			
TOTAL	4919.6	35				

(vi) Higher order repetition analysis for the 1000 msec interstimulus interval compatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	966.58	5	193.32			
2 (differences between sequence lengths)	2.6667	2	1.3333	2/1x2	<1	
3 (difference between the differences)	1586.7	1	1586.7	3/1x3	11.80	<.025
1x2	489.00	10	48.900			
1x3	672.14	5	134.43			
2x3	654.89	2	327.44	2x3/1x2x3	6.39	<.025
1x2x3	512.78	10	51.278			
TOTAL	4884.8	35				

(vii) Higher order alternation analysis for the 1000 msec inter-stimulus interval incompatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1499.6	5	299.91			
2 (differences between sequence lengths)	1200.1	2	600.03	2/1x2	5.35	<.05
3 (difference between the differences)	2988.4	1	2988.4	3/1x3	11.99	<.025
1x2	1122.3	10	112.23			
1x3	1246.2	5	249.24			
2x3	45.389	2	22.694	2x3/1x2x3	<1	
1x2x3	1904.9	10	190.49			
TOTAL	10007	35				

(viii) Higher order repetition analysis for the 1000 msec inter-stimulus interval incompatible stimulus - response condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	498.33	5	99.667			
2 (differences between sequence lengths)	186.50	2	93.250	2/1x2	<1	
3 (difference between the differences)	900.00	1	900.00	3/1x3	3.13	n.s.
1x2	1683.2	10	168.32			
1x3	1436.3	5	287.27			
2x3	652.17	2	326.08	2x3/1x2x3	2.12	n.s.
1x2x3	1539.5	10	153.95			
TOTAL	6896.0	35				

APPENDIX 5.3

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 4.

(i) Mean reaction time (msec) .

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	137197	5	27439			
2 (number of runs)	4178.7	2	2089.3	2/1x2	2.49	n.s.
3 (interstimulus interval)	56882	1	56882	3/1x3	7.12	<.05
1x2	8404.7	10	840.47			
1x3	39942	5	7988.3			
2x3	78.000	2	39.000	2x3/1x2x3	<1	
1x2x3	3538.7	10	353.87			
TOTAL	250221	35				

(ii) Difference between reaction times for AA and BA (msec)

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	70911	5	14182			
2 (number of runs)	2040.7	2	1020.3	2/1x2	3.08	n.s.
3 (interstimulus interval)	8160.1	1	8160.1	3/1x3	<1	
1x2	3313.7	10	331.37			
1x3	51882	5	10376			
2x3	88.889	2	44.444	2x3/1x2x3	<1	
1x2x3	4098.1	10	409.81			
TOTAL	140494	35				

(iii) Higher order alternation analysis for the 2000 msec inter-stimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	464.16	5	92.831			
2 (differences between sequence lengths)	652.91	2	326.45	2/1x2	<1	
3 (difference between the differences)	4498.2	1	4498.2	3/1x3	24.61	<.01
4 (number of runs)	47.630	2	23.815	4/1x4	<1	
1x2	4243.6	10	424.36			
1x3	913.94	5	182.79			
1x4	2897.3	10	289.73			
2x3	325.02	2	162.51	2x3/1x2x3	<1	
2x4	321.93	4	80.481	2x4/1x2x4	<1	
3x4	107.19	2	53.593	3x4/1x3x4	<1	
1x2x3	2162.0	10	216.20			
1x2x4	3454.5	20	172.73			
1x3x4	1675.5	10	167.55			
2x3x4	477.81	4	119.45	2x3x4/ 1x2x3x4	<1	
1x2x3x4	3992.9	20	199.64			
TOTAL	26235	107				

(iv) Higher order repetition analysis for the 2000 msec inter-stimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	2590.0	5	518.01			
2 (differences between sequence lenghts)	1465.9	2	732.95	2/1x2	2.39	n.s.
3 (difference between the differences)	3616.9	1	3616.9	3/1x3	14.23	<.05
4 (number of runs)	213.46	2	106.73	4/1x4	<1	
1x2	3066.2	10	306.62			
1x3	1270.7	5	254.14			
1x4	1406.0	10	140.60			
2x3	1358.5	2	679.23	2x3/1x2x3	2.88	n.s.
2x4	2136.9	4	534.22	2x4/1x2x4	2.82	n.s.
3x4	1806.8	2	903.40	3x4/1x3x4	4.21	<.05
1x2x3	2360.8	10	236.08			
1x2x4	3783.0	20	189.15			
1x3x4	2143.8	10	214.38			
2x3x4	243.43	4	60.856	2x3x4/ 1x2x3x4	<1	
1x2x3x4	4992.7	20	249.63			
TOTAL	32455	107				

(v) Higher order alternation analysis for the 1 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	3056.9	5	611.39			
2 (differences between sequence lengths)	1777.0	2	888.51	2/1x2	1.25	n.s.
3 (difference between the differences)	7121.6	1	7121.6	3/1x3	4.42	n.s.
4 (number of runs)	1644.2	2	822.12	4/1x4	3.06	n.s.
1x2	7096.8	10	709.68			
1x3	8064.0	5	1612.8			
1x4	2688.9	10	268.89			
2x3	874.02	2	437.01	2x3/1x2x3	<1	
2x4	4071.0	4	1017.8	2x4/1x2x4	1.63	n.s.
3x4	29.463	2	14.731	3x4/1x3x4	<1	
1x2x3	10675	10	1067.5			
1x2x4	12482	20	624.08			
1x3x4	1362.1	10	136.21			
2x3x4	2439.7	4	609.93	2x3x4/ 1x2x3x4	1.80	n.s.
1x2x3x4	6791.7	20	339.59			
TOTAL	70174	107				

(vi) Higher order repetition analysis for the 1 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	12046	5	2409.1			
2 (differences between sequence lengths)	3001.7	2	1500.8	2/1x2	1.02	n.s.
3 (difference between the differences)	10.704	1	10.704	3/1x3	<1	
4 (number of runs)	218.35	2	109.18	4/1x4	<1	
1x2	14693	10	1469.3			
1x3	13080	5	2615.9			
1x4	4934.2	10	493.42			
2x3	2765.9	2	1383.0	2x3/1x2x3	1.56	n.s.
2x4	2484.3	4	621.05	2x4/1x2x4	1.09	n.s.
3x4	907.35	2	453.68	3x4/1x3x4	<1	
1x2x3	8887.9	10	888.79			
1x2x4	11429	20	571.44			
1x3x4	5256.8	10	525.68			
2x3x4	5502.7	4	1375.7	2x3x4/ 1x2x3x4	2.51	n.s.
1x2x3x4	10946	20	547.31			
TOTAL	96164	107				

APPENDIX 6.1

RELATED SAMPLES T TESTS FOR EXPERIMENT 5.

Comparing the difference between the reaction time for AA and BA (msec) for:

(i) the first six runs of the 2000 msec interstimulus interval condition

$t = 4.58$, d.f. = 5, $P < .01$

(ii) the first six runs of the 50 msec interstimulus interval condition

$t = 1.04$, d.f. = 5, n.s.

(iii) preparation for repetitions with the 2000 msec interstimulus interval

$t = 2.82$, d.f. = 5, $P < .05$

(iv) preparation for repetitions with the 50 msec interstimulus interval

$t = 3.40$, d.f. = 5, $P < .05$

(v) preparation for alternation with the 2000 msec interstimulus interval

$t = 5.05$, d.f. = 5, $P < .005$

(vi) preparation for alternations with the 50 msec interstimulus interval

$t = 1.75$, d.f. = 5, n.s.

(vii) the last three runs of the 2000 msec interstimulus interval condition

$t < 1$, d.f. = 5

(viii) the last three runs of the 50 msec interstimulus interval condition (Wilcoxon matched pairs signed-ranks test)

$T = 0$, $N = 6$, $P < .05$

Comparison between the overall mean reaction time (msec) for:

(i) the preparation for repetitions and preparation for alternations conditions with the 2000 msec interstimulus interval

$t < 1$, d.f. = 5,

(ii) the preparation for repetitions and preparation for alternations conditions with the 50 msec interstimulus interval

$t < 1$, d.f. = 5.

Comparison between the reaction time for a prepared repetition and a prepared alternation for:

(i) the 2000 msec interstimulus interval condition

$t = 1.28$, d.f. = 5, n.s.,

(ii) the 50 msec interstimulus interval condition

$t = 2.98$, d.f. = 5, $P < .05$.

APPENDIX 6.2

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 5.

(i) Higher order alternation analysis for the first six runs of the 2000 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	212.58	5	42.517			
2 (differences between sequence lengths)	17.167	2	8.5833	2/1x2	<1	
3 (difference between the differences)	812.25	1	812.25	3/1x3	4.59	n.s.
1x2	605.50	10	60.550			
1x3	884.58	5	176.92			
2x3	127.17	2	63.583	2x3/1x2x3	<1	
1x2x3	723.50	10	72.350			
TOTAL	3382.7	35				

(ii) Higher order repetition analysis for the first six runs of the 2000 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1258.9	5	251.78			
2 (differences between sequence lengths)	108.50	2	54.250	2/1x2	<1	
3 (difference between the differences)	812.25	1	812.25	3/1x3	6.34	n.s.
1x2	1070.8	10	107.08			
1x3	640.25	5	128.05			
2x3	58.500	2	29.250	2x3/1x2x3	<1	
1x2x3	637.50	10	63.750			
TOTAL	4586.7	35				

(iii) Higher order alternation analysis for the preparation for repetitions condition with the 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1411.3	5	282.27			
2 (differences between sequence lengths)	2053.2	2	1026.6	2/1x2	5.30	<.05
3 (difference between the differences)	2466.8	1	2466.8	3/1x3	7.92	<.05
1x2	1938.5	10	193.85			
1x3	1558.2	5	311.64			
2x3	61.056	2	30.528	2x3/1x2x3	<1	
1x2x3	1383.9	10	138.39			
TOTAL	10873	35				

(iv) Higher order repetition analysis for the preparation for repetitions condition with the 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1625.6	5	325.11			
2 (differences between sequence lengths)	251.06	2	125.53	2/1x2	<1	
3 (difference between the differences)	169.00	1	169.00	3/1x3	<1	
1x2	6325.3	10	632.53			
1x3	1472.0	5	294.40			
2x3	1153.5	2	576.75	2x3/1x2x3	1.33	n.s.
1x2x3	4331.5	10	433.15			
TOTAL	15328	35				

(v) Higher order alternation analysis for the preparation for alternations condition with the 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	435.00	5	87.000			
2 (differences between sequence lengths)	618.50	2	309.25	2/1x2	1.14	n.s.
3 (difference between the differences)	1495.1	1	1495.1	3/1x3	2.65	n.s.
1x2	2714.5	10	271.45			
1x3	2819.9	5	563.98			
2x3	986.72	2	493.36	2x3/1x2x3	1.97	n.s.
1x2x3	2506.3	10	250.63			
TOTAL	11576	35				

(vi) Higher order repetition analysis for the preparation for alternations condition with the 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	943.22	5	188.64			
2 (differences between sequence lengths)	214.06	2	107.03	2/1x2	<1	n.s.
3 (difference betweeen the differences)	560.11	1	560.11	3/1x3	7.42	<.05
1x2	2304.9	10	230.49			
1x3	377.22	5	75.444			
2x3	70.389	2	35.194	2x3/1x2x3	<1	
1x2x3	2389.3	10	238.93			
TOTAL	6859.2	35				

(vii) Higher order alternation analysis for the last three runs of the 2000 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1643.5	5	328.69			
2 (differences between sequence lengths)	67.389	2	33.694	2/1x2	<1	
3 (difference between the differences)	4074.7	1	4074.7	3/1x3	8.45	<.05
1x2	3433.3	10	343.33			
1x3	2411.5	5	482.29			
2x3	360.72	2	180.36	2x3/1x2x3	<1	
1x2x3	2828.6	10	282.86			
TOTAL	14820	35				

(viii) Higher order repetition analysis for the last three runs of the 20000 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	878.00	5	175.60			
2 (differences between sequence lengths)	1431.2	2	715.58	2/1x2	3.85	n.s.
3 (difference between the differences)	2738.8	1	2738.8	3/1x3	13.11	<.025
1x2	1860.8	10	186.08			
1x3	1044.2	5	208.84			
2x3	86.722	2	43.461	2x3/1x2x3	<1	
1x2x3	2393.3	10	139.33			
TOTAL	10433	35				

(ix) Higher order alternation analysis for the first six runs of the 50 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1222.3	5	242.27			
2 (differences between sequence lengths)	195.17	2	97.583	2/1x2	1.29	n.s.
3 (difference between the differences)	7056.0	1	7056.0	3/1x3	35.87	<.005
1x2	755.50	10	75.550			
1x3	983.67	5	196.73			
2x3	54.167	2	27.083	2x3/1x2x3	<1	
1x2x3	4547.2	10	454.72			
TOTAL	14803	35				

(x) Higher order repetition analysis for the first six runs of the 50 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	285.33	5	57.067			
2 (differences between sequence lengths)	1090.2	2	545.08	2/1x2	3.15	n.s.
3 (difference between the differences)	1681.0	1	1681.0	3/1x3	6.14	n.s.
1x2	1732.5	10	173.25			
1x3	1369.7	5	273.93			
2x3	1128.2	2	564.08	2x3/1x2x3	4.77	<.05
1x2x3	1183.2	10	118.32			
TOTAL	8470.1	35				

(xi) Higher order alternation analysis for the preparation for repettitions condition with the 50 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	2249.2	5	449.84			
2 (differences between sequence lengths)	2050.1	2	1025.0	2/1x2	2.13	n.s.
3 (difference between the differences)	1626.8	1	1626.8	3/1x3	1.65	n.s.
1x2	4812.9	10	481.29			
1x3	4919.6	5	983.91			
2x3	534.39	2	267.19	2x3/1x2x3	1.18	n.s.
1x2x3	2269.3	10	226.93			
TOTAL	18462	35				

(xii) Higher order repetition analysis for the preparation for repetitions condition with the 50 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	161.89	5	32.378			
2 (differences between sequence lengths)	1446.2	2	723.11	2/1x2	2.27	n.s.
3 (difference between the differences)	2567.1	1	2567.1	3/1x3	17.71	<.01
1x2	3179.1	10	317.91			
1x3	724.89	5	144.98			
2x3	80.222	2	40.111	2x3/1x2x3	<1	
1x2x3	4693.8	10	469.38			
TOTAL	12853	35				

(xiii) Higher order alternation analysis for the preparation for alternations condition with the 50 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	3943.3	5	788.67			
2 (differences between sequence lengths)	1878.5	2	939.25	2/1x2	1.25	n.s.
3 (difference between the differences)	3600.0	1	3600.0	3/1x3	4.39	n.s.
1x2	7525.2	10	752.52			
1x3	4103.3	5	820.67			
2x3	345.17	2	172.58	2x3/1x2x3	<1	
1x2x3	10528	10	1052.8			
TOTAL	31923	35				

(xiv) Higher order repetition analysis for the preparation for alternations condition with the 50 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	8984.9	5	1797.0			
2 (differences between sequence lengths)	1727.2	2	863.58	2/1x2	2.48	n.s.
3 (difference between the differences)	173.36	1	173.36	3/1x3	<1	
1x2	3488.2	10	348.82			
1x3	2877.1	5	575.43			
2x3	1768.7	2	884.36	2x3/1x2x3	2.22	n.s.
1x2x3	3989.3	10	398.93			
TOTAL	23009	35				

(xv) Higher order alternation analysis for the last three runs of the 50 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	683.58	5	136.72			
2 (differences between sequence lengths)	1030.5	2	515.25	2/1x2	2.62	n.s.
3 (difference between the differences)	2040.0	1	2040.0	3/1x3	5.07	n.s.
1x2	1963.2	10	196.32			
1x3	2013.1	5	402.63			
2x3	735.39	2	367.69	2x3/1x2x3	1.55	n.s.
1x2x3	2376.9	10	237.69			
TOTAL	10843	35				

(xvi) Higher order repetition analysis for the last three runs of the 50 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	619.92	5	123.98			
2 (differences between sequence lengths)	1071.2	2	535.58	2/1x2	1.60	n.s.
3 (difference between the differences)	90.250	1	90.250	3/1x3	<1	
1x2	3340.2	10	334.02			
1x3	581.25	5	116.25			
2x3	8.1667	2	4.0833	2x3/1x2x3	<1	
1x2x3	1645.8	10	164.58			
TOTAL	7356.8	35				

APPENDIX 6.3

RELATED SAMPLES T TESTS FOR EXPERIMENT 6.

Comparing the reaction times for AA and BA (msec) for:

(i) the 60% alternations condition

$t = 4.20$, d.f. = 5, $P < .01$,

(ii) the 60% repetitions condition

$t = 1.77$, d.f. = 5, n.s.,

(iii) the 50% repetitions condition

$t = 3.06$, d.f. = 5, $P < .05$.

APPENDIX 6.4

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 6.

(i) Mean reaction time

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	86244	5	17249			
2 (different instructions)	368.11	2	184.06	2/1x2	<1	
1x2	2333.9	10	233.39			
TOTAL	88946	17				

(ii) Difference between reaction times for AA and BA (msec)

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	5807.3	5	1161.5			
2 (different instructions)	17.333	2	8.6667	2/1x2	<1	
1x2	1635.3	10	163.53			
TOTAL	7459.9	17				

(iii) Higher order alternation analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1148.5	5	229.71			
2 (differences between sequence lengths)	235.72	2	117.86	2/1x2	<1	
3 (difference between the differences)	1064.1	1	1064.1	3/1x3	37.16	< .005
4 (different instructions)	288.89	2	144.44	4/1x4	<1	
1x2	2318.8	10	231.88			
1x3	143.19	5	28.639			
1x4	3844.0	10	384.40			
2x3	1696.7	2	848.36	2x3/1x2x3	3.56	n.s.
2x4	331.56	4	82.889	2x4/1x2x4	<1	
3x4	68.222	2	34.111	3x4/1x3x4	<1	
1x2x3	2385.8	10	238.58			
1x2x4	3571.9	20	178.59			
1x3x4	1284.0	10	128.40			
2x3x4	304.56	4	76.139	2x3x4/ 1x2x3x4	<1	
1x2x3x4	3296.9	20	164.84			
TOTAL	21983	107				

(iv) Higher order <u>repetition</u> analysis

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	553.94	5	110.79			
2 (differences between sequence lengths)	171.24	2	85.620	2/1x2	<1	
3 (difference between the differences)	1784.5	1	1784.5	3/1x3	6.79	<.05
4 (different instuctions)	298.30	2	149.15	4/1x4	1.37	n.s.
1x2	981.65	10	98.165			
1x3	1313.5	5	262.70			
1x4	1085.3	10	108.53			
2x3	239.69	2	119.84	2x3/1x2x3	1.15	n.s.
2x4	1031.7	4	257.93	2x4/1x2x4	3.26	<.05
3x4	40.074	2	20.037	3x4/1x3x4	<1	
1x2x3	1039.2	10	103.92			
1x2x4	1580.4	20	79.020			
1x3x4	724.81	10	72.481			
2x3x4	320.04	4	80.009	2x3x4/ 1x2x3x4	<1	
1x2x3x4	1966.7	20	98.337			
TOTAL	13131	107				

APPENDIX 6.5

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 7.

2000 msec interstimulus interval condition

(i) mean reaction time (msec) for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	14558	5	2911.7			
2 (different instructions)	117.44	2	58.722	2/1x2	<1	
1x2	1399.9	10	139.99			
TOTAL	16075	17				

(ii) mean reaction time (msec) for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	10639	5	2127.9			
2 (different instructions)	70.333	2	35.167	2/1x2	<1	
1x2	2370.3	10	237.03			
TOTAL	13080	17				

(iii) Difference between reaction times for AA and BA (msec) for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1220.5	5	244.10			
2 (different instructions)	10516	2	5258.2	2/1x2	12.89	<.005
1x2	4079.7	10	407.97			
TOTAL	15816	17				

(iv) Difference between reaction times for AA and BA (msec) for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1168.4	5	233.69			
2 (different instructions)	2027.1	2	1013.6	2/1x2	4.97	<.05
1x2	2038.2	10	203.82			
TOTAL	5233.7	17				

(v) Higher order alternation analysis for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	348.61	5	69.722			
2 (differences between sequence lengths)	430.22	1	430.22	2/1x2	1.50	n.s.
3 (differences between the differences)	1800.0	1	1800.0	3/1x3	25.60	<.005
4 (different instructions)	17.694	2	8.8472	4/1x4	<1	
1x2	1431.4	5	286.29			
1x3	352.00	5	70.400			
1x4	610.97	10	61.097			
2x3	249.39	1	249.39	2x3/1x2x3	8.12	<.05
2x4	97.861	2	48.931	2x4/1x2x4	1.02	n.s.
3x4	344.08	2	172.04	3x4/1x3x4	8.78	<.01
1x2x3	153.61	5	30.722			
1x2x4	479.47	10	47.947			
1x3x4	195.92	10	19.592			
2x3x4	244.36	2	122.18	2x3x4/ 1x2x3x4	1.47	n.s.
1x2x3x4	831.64	10	83.164			
TOTAL	7587.2	71				

(vi) Higher order <u>repetition</u> analysis for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1028.7	5	205.75			
2 (differences between sequence lengths)	238.35	1	238.35	2/1x2	2.49	n.s.
3 (difference between the differences)	1326.1	1	1326.1	3/1x3	31.83	<.005
4 (different instructions)	70.028	2	35.014	4/1x4	<1	
1x2	479.40	5	95.881			
1x3	208.29	5	41.658			
1x4	929.81	10	92.981			
2x3	465.12	1	465.12	2x3/1x2x3	3.89	n.s.
2x4	25.861	2	12.931	2x4/1x2x4	<1	
3x4	249.08	2	124.54	3x4/1x3x4	1.08	n.s.
1x2x3	598.29	5	119.66			
1x2x4	1197.6	10	119.76			
1x3x4	1152.7	10	115.27			
2x3x4	115.58	2	57.792	2x3x4/ 1x2x3x4	<1	
1x2x3x4	1923.2	10	192.32			
TOTAL	10008	71				

(vii) Higher order alternation analysis for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	652.74	5	130.55			
2 (differences between sequence lengths)	260.68	1	260.68	2/1x2	2.84	n.s.
3 (difference between the differences)	2323.3	1	2323.3	3/1x3	30.54	<.005
4 (different instructions)	13.028	2	6.5139	4/1x4	<1	
1x2	459.40	5	91.881			
1x3	380.40	5	76.081			
1x4	707.14	10	70.714			
2x3	.01389	1	.01389	2x3/1x2x3	<1	
2x4	172.86	2	86.431	2x4/1x2x4	<1	
3x4	730.53	2	365.26	3x4/1x3x4	4.61	<.05
1x2x3	361.07	5	72.214			
1x2x4	1205.3	10	120.53			
1x3x4	792.97	10	79.297			
2x3x4	66.694	2	33.347	2x3x4/ 1x2x3x4	1.01	n.s.
1x2x3x4	331.47	10	33.147			
TOTAL	8957.7	71				

(viii) Higher order <u>repetition</u> analysis for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1701.9	5	340.38			
2 (differences between sequence lengths)	183.68	1	183.68	2/1x2	2.51	n.s.
3 (difference between the differences)	1711.1	1	1711.1	3/1x3	15.19	<.025
4 (different instructions)	438.03	2	219.01	4/1x4	1.60	n.s.
1x2	365.57	5	73.114			
1x3	582.79	5	116.57			
1x4	1368.0	10	136.80			
2x3	70.014	1	70.014	2x3/1x2x3	<1	
2x4	4.5278	2	2.2369	2x4/1x2x4	<1	
3x4	1155.6	2	577.79	3x4/1x3x4	3.10	n.s.
1x2x3	379.90	5	75.981			
1x2x4	740.47	10	74.047			
1x3x4	1861.7	10	186.17			
2x3x4	355.19	2	177.60	2x3x4/ 1x2x3x4	1.20	n.s.
1x2x3x4	1485.1	10	148.51			
TOTAL	12404	71				

1 msec interstimulus interval condition

(i) mean reaction time (msec) for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	22736	5	4547.2			
2 (different instructions)	13461	2	6730.7	2/1x2	<1	n.s.
1x2	71991	10	7199.1			
TOTAL	108188	17				

(ii) mean reaction time (msec) for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	7481.8	5	1496.4			
2 (different instructions)	4869.8	2	2434.9	2/1x2	<1	
1x2	25847	10	2584.7			
TOTAL	38198	17				

(iii) Difference between reaction times for AA and BA (msec) for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	23606	5	4721.3			
2 (different instructions)	36594	2	18297	2/1x2	39.75	<.005
1x2	4602.6	10	460.26			
TOTAL	64802	17				

(iv) Difference between reaction times for AA and BA (msec) for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	39886	5	7977.3			
2 (different instructions)	9352.8	2	5676.4	2/1x2	4.61	<.05
1x2	10155	10	1015.5			
TOTAL	59394	17				

(v) Higher order alternation analysis for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	14600	5	2920.0			
2 (differences between sequence lengths)	3213.3	1	3213.3	2/1x2	3.23	n.s.
3 (difference between the differences)	4340.0	1	4340.0	3/1x3	2.47	n.s.
4 (different instructions)	1513.1	2	756.54	4/1x4	<1	
1x2	4977.2	5	995.45			
1x3	8771.6	5	1754.3			
1x4	20738	10	2073.8			
2x3	245.68	1	245.68	2x3/1x2x3	<1	
2x4	1055.0	2	527.51	2x4/1x2x4	<1	
3x4	423.03	2	211.51	3x4/1x3x4	<1	
1x2x3	6696.2	5	1339.2			
1x2x4	7097.6	10	709.76			
1x3x4	13711	10	1371.1			
2x3x4	954.19	2	477.10	2x3x4/ 1x2x3x4	<1	
1x2x3x4	10539	10	1053.9			
TOTAL	98875	71				

(vi) Higher order <u>repetition</u> analysis for the first 200 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1448.6	5	289.71			
2 (differences between sequence lengths)	62.347	1	62.347	2/1x2	<1	
3 (difference between the differences)	6328.1	1	6328.1	3/1x3	31.06	<.005
4 (different instructions)	1210.9	2	605.43	4/1x4	3.36	n.s.
1x2	1846.9	5	369.38			
1x3	1018.8	5	203.76			
1x4	1803.1	10	180.31			
2x3	465.12	1	465.12	2x3/1x2x3	1	
2x4	1480.5	2	740.26	2x4/1x2x4	3.79	n.s.
3x4	3913.6	2	1956.8	3x4/1x3x4	11.94	<.005
1x2x3	3065.1	5	613.02			
1x2x4	1954.5	10	195.45			
1x3x4	1638.7	10	163.87			
2x3x4	128.25	2	64.125	2x3x4/ 1x2x3x4	<1	
1x2x3x4	4639.7	10	463.97			
TOTAL	31004	71				

(vii) Higher order <u>alternation</u> analysis for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1674.6	5	334.91			
2 (differences between sequence lengths)	715.68	1	715.68	2/1x2	1.39	n.s.
3 (difference between the differences)	16471	1	16471	3/1x3	15.26	$<.025$
4 (different instructions)	1124.7	2	562.35	4/1x4	2.61	n.s.
1x2	2570.6	5	514.11			
1x3	5397.5	5	1079.5			
1x4	2153.6	10	215.36			
2x3	51.681	1	51.681	2x3/1x2x3	<1	
2x4	1021.7	2	510.85	2x4/1x2x4	2.87	n.s.
3x4	2625.6	2	1312.8	3x4/1x3x4	1.70	
1x2x3	5128.2	5	1025.6			
1x2x4	1780.3	10	178.03			
1x3x4	7720.1	10	772.01			
2x3x4	171.36	2	85.681	2x3x4/ 1x2x3x4	<1	
1x2x3x4	1958.0	10	195.80			
TOTAL	50565	71				

(viii) Higher order repetition analysis for the last 100 trials

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1969.8	5	393.96			
2 (differences between sequence lengths)	28.125	1	28.125	2/1x2	< 1	
3 (difference between the differences)	11325	1	11325	3/1x3	11.20	< .025
4 (different instructions)	470.58	2	235.29	4/1x4	2.69	n.s.
1x2	767.79	5	153.56			
1x3	5054.5	5	1010.9			
1x4	873.25	10	87.325			
2x3	7421.7	1	7421.7	2x3/1x2x3	22.67	< .01
2x4	1011.6	2	505.79	2x4/1x2x4	2.09	n.s.
3x4	936.58	2	468.29	3x4/1x3x4	2.27	n.s.
1x2x3	1635.6	5	327.11			
1x2x4	2424.2	10	242.42			
1x3x4	2061.6	10	206.16			
2x3x4	67.694	2	33.847	2x3x4 / 1x2x3x4	< 1	
1x2x3x4	2369.8	10	236.98			
TOTAL	38418	71				

APPENDIX 7.1

ANALYSIS OF VARIANCE SUMMARY TABLES
FOR EXPERIMENT 8.

2000 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	984660	5	196932			
2 (REP/SHNR/OH)	237653	2	118826	2/1x2	33.23	<.005
3 (fingers)	444536	3	148179	3/1x3	3.17	n.s.
1x2	35759	10	3575.9			
1x3	290493	15	19366			
2x3	50635	6	8439.2	2x3/1x2x3	4.45	<.005
1x2x3	56942	30	1898.1			
TOTAL	2100678	71				

1 msec interstimulus interval condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	1271140	5	254228			
2 (REP/SHNR/OH)	420223	2	210112	2/1x2	10.90	<.005
3 (fingers)	409593	3	136531	3/1x3	18.33	<.005
1x2	192808	10	19281			
1x3	111720	15	7448.0			
2x3	205840	6	34307	2x3/1x2x3	4.23	<.005
1x2x3	243049	30	8101.6			
TOTAL	2854733	71				

APPENDIX 7.2

RELATED SAMPLES T TESTS FOR EXPERIMENT 8.

(i) Difference between the overall repetition effects for the 1 msec and 2000 msec ISI conditions
$t < 1$, d.f. = 5,

Difference between the RT to the repetition response and the RT to responses immediately adjacent to the repetition response for:

(ii) 2000 msec ISI condition
$t = 3.67$, d.f. = 5, $P < .02$

(iii) 1 msec ISI condition
$t < 1$, d.f. = 5

(iv) Difference between the 1 msec and 2000 msec ISIs of the differences between Inner REP and Inner OH response RTs.
$t = 2.16$, d.f. = 5, $P < .05$ (one tailed)

APPENDIX 7.3

DUNCAN MULTIPLE RANGE TESTS FOR EXPERIMENT 8.

Any two treatment means not underscored by the same line are significantly different
Any two treatment means underscored by the same line are not significantly different

(i) 2000 msec interstimulus interval condition

		A	B	C	D	E	F	G	H	I	J	K	L
		487	506	525	540	561	571	574	574	595	628	666	690
A	487		19	38	53	74	84	87	87	108	141	179	203
B	506			19	34	55	65	68	68	89	122	160	184
C	525				15	36	46	49	49	70	103	141	165
D	540					21	31	34	34	55	88	126	160
E	561						10	13	13	34	67	105	129
F	571							3	3	24	57	95	119
G	574									21	54	92	116
H	574									21	54	92	116
I	595										33	71	95
J	628											38	72
K	666												24
		A	B	C	D	E	F	G	H	I	J	K	L

shortest significant ranges $F < .05$

$R_2 = 51.4$
$R_3 = 54.0$
$R_4 = 55.7$
$R_5 = 56.9$
$R_6 = 57.8$
$R_7 = 58.5$
$R_8 = 59.1$
$R_9 = 59.6$
$R_{10} = 60.0$
$R_{11} = 60.3$
$R_{12} = 60.6$

Table of the above mean reaction times

	Finger			
	Index	Middle	Ring	Little
REP	487	574	574	506
SHNR	561	628	595	525
OH	571	690	666	540

(ii) 1 msec interstimulus interval condition

		A	B	C	D	E	F	G	H	I	J	K	L
MEANS		576	593	613	619	623	629	641	660	661	689	786	817
A	576		17	37	43	47	53	65	84	85	113	210	241
B	593			20	26	30	36	48	67	68	96	193	224
C	613				6	10	16	28	47	48	76	173	204
D	619					4	10	22	41	42	70	167	198
E	623						6	18	37	38	66	163	194
F	629							12	31	32	60	157	188
G	641								19	20	48	145	176
H	660									1	29	126	157
I	661										28	125	156
J	689											97	128
K	786												21
		A	B	C	D	E	F	G	H	I	J	K	L

shortest significant ranges $P < .05$

$R_2 = 106.1$
$R_3 = 111.5$
$R_4 = 115.0$
$R_5 = 117.5$
$R_6 = 119.4$
$R_7 = 120.9$
$R_8 = 122.1$
$R_9 = 123.0$
$R_{10} = 123.9$
$R_{11} = 124.5$
$R_{12} = 125.1$

Table of the above mean reaction times

	Finger			
	Index	Middle	Ring	Little
REP	613	629	623	593
SHNR	661	689	641	576
OH	660	817	786	619

APPENDIX 8.1

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 9.

(i) Both hands compatible condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	157985	5	31597			
2 (REP/SHNR/OH)	120737	2	60368	2/1x2	39.19	<.005
3 (fingers)	59443	3	19814	3/1x3	13.28	<.005
1x2	15404	10	1540.4			
1x3	22384	15	1492.3			
2x3	33367	6	5561.2	2x3/1x2x3	6.33	.005
1x2x3	26353	30	878.44			
TOTAL	435673	71				

(ii) Both hands incompatible condition

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	451180	5	90236			
2 (REP/SHNR/OH)	146417	2	73209	2/1x2	55.01	<.005
3 (fingers)	44476	3	14825	3/1x3	3.53	<.05
1x2	13308	10	1330.8			
1x3	63028	15	4201.9			
2x3	5572.9	6	928.81	2x3/1x2x3	1.34	n.s.
1x2x3	20816	30	693.86			
TOTAL	744798	71				

(iii) <u>One hand compatible - one hand incompatible condition</u>

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	462525	5	92505			
2 (REP/SHNR/OH)	134324	1	67162	2/1x2	24.33	<.005
3 (Inner/Outer)	13203	1	13203	3/1x3	3.58	n.s.
4 (compatible/ incompatible)	62835	1	62835	4/1x4	7.79	<.05
1x2	27604	10	2760.4			
1x3	18440	5	3687.9			
1x4	40338	5	8067.6			
2x3	608.58	2	304.29	2x3/1x2x3	<1	
2x4	18586	2	9292.8	2x4/1x2x4	20.14	<.005
3x4	17641	1	17641	3x4/1x3x4	14.59	<.025
1x2x3	3278.9	10	327.89			
1x2x4	4614.6	10	461.46			
1x3x4	6045.7	5	1209.1			
2x3x4	4864.5	2	2432.3	2x3x4/ 1x2x3x4	1.80	n.s.
1x2x3x4	13535	10	1353.5			
TOTAL	828443	71				

APPENDIX 8.2

RELATED SAMPLES T TESTS FOR EXPERIMENT 9.

Comparing the RT to the repetition response and the RT to responses immediately adjacent to the repetition response for:

(i) Both hands compatible condition
$t = 2.4$, d.f. = 5, n.s.

(ii) Both hands incompatible condition
$t = 3.75$, d.f. = 5, $P < .02$

(iii) One hand compatible condition
$t = 1.02$, d.f. = 5, n.s.

(iv) One hand incompatible condition
$t = 5.94$, d.f. = 5, $P < .01$

Comparing the RT to the repetition stimulus with the RT to stimuli immediately adjacent to the repetition stimulus for:

(i) Both hands incompatible condition
$t = 5.58$, d.f. = 5, $P < .01$

(ii) Both hands incompatible condition
$t = 2.93$, d.f. = 5, $P < .05$

APPENDIX 8.3

DUNCAN MULTIPLE RANGE TESTS FOR EXPERIMENT 9.

Any two treatment means not underscored by the same line are significantly different
Any two treatment means underscored by the same line are not significantly different

(i) Both hands compatible condition

Comparing REP, SHNR and OH mean reaction times for the four fingers

		A	B	C	D	E	F	G	H	I	J	K	L
MEANS		444	473	479	480	499	502	503	526	536	542	625	629
A	444		29	35	36	55	58	59	82	92	93	181	185
B	473			6	7	26	29	30	53	63	69	152	156
C	479				1	20	23	24	47	57	63	146	150
D	480					19	22	23	46	56	62	145	149
E	499						3	4	27	37	43	126	130
F	502							1	24	34	40	123	127
G	503								23	33	39	122	128
H	526									10	16	99	103
I	536										6	89	93
J	542											83	87
K	625												4

shortest significant ranges $P < .05$

$R_2 = 34.9$
$R_3 = 36.7$
$R_4 = 37.9$
$R_5 = 38.7$
$R_6 = 39.3$
$R_7 = 39.8$
$R_8 = 40.2$
$R_9 = 40.5$
$R_{10} = 40.8$
$R_{11} = 41.0$
$R_{12} = 41.2$

A B C D E F G H I J K L

Table of the above mean reaction times

	Finger			
	Index	Middle	Ring	Little
REP	444	473	503	479
SHNR	499	536	526	480
OH	542	629	625	502

(ii) <u>Both hands incompatible condition</u>

Comparing REP, SHNR and OH mean reaction times for the four fingers

		A	B	C	D	E	F	G	H	I	J	K	L	shortest significant ranges $P < .05$
MEANS		576	587	594	629	642	646	660	683	686	693	697	768	
A	576		11	18	53	66	70	84	107	110	117	121	192	$R_2 = 31.1$
B	587			7	42	55	59	73	96	99	106	110	181	$R_3 = 32.6$
C	594				35	48	52	66	89	92	99	103	174	$R_4 = 33.7$
D	629					13	17	31	54	57	64	68	139	$R_5 = 34.4$
E	642						4	18	41	44	51	55	126	$R_6 = 34.9$
F	646							14	37	40	47	51	122	$R_7 = 35.4$
G	660								23	26	33	37	108	$R_8 = 35.7$
H	683									3	10	14	85	$R_9 = 36.0$
I	686										7	12	82	$R_{10} = 36.2$
J	693											4	75	$R_{11} = 36.4$
K	697												71	$R_{12} = 36.6$

A B C D E F G H I J K L

Table of the above mean reaction times

	Finger			
	Index	Middle	Ring	Little
REP	594	587	576	629
SHNR	660	642	646	686
OH	697	693	683	768

(iii) <u>One hand compatible - one hand incompatible condition</u>

Comparing REP, SHNR and OH Inner and Outer mean reaction times

		A	B	C	D	E	F	G	H	I	J	K	L	shortest significant ranges $P<.05$
MEANS		567	594	607	618	620	632	635	703	717	721	731	764	
A	567		27	40	51	53	65	68	136	150	154	164	197	$R_2 = 47.5$
B	594			13	24	26	38	41	109	123	127	137	170	$R_3 = 49.6$
C	607				11	13	25	28	96	110	114	124	157	$R_4 = 50.9$
D	618					2	14	17	85	99	103	113	146	$R_5 = 51.7$
E	620						12	15	83	97	101	111	144	$R_6 = 52.2$
F	632							3	71	85	89	99	132	$R_7 = 52.6$
G	635								18	82	86	96	129	$R_8 = 52.8$
H	703									14	18	28	61	$R_9 = 53.0$
I	717										4	14	47	$R_{10} = 53.1$
J	721											10	43	$R_{11} = 53.1$
K	731												33	$R_{12} = 53.1$

A B C D E F G H I J K L

Table of the above mean reaction times

	Stimulus - response arrangement			
	Compatible Fingers		Incompatible Fingers	
	Outer	Inner	Outer	Inner
REP	567	620	618	607
SHNR	594	632	703	717
OH	635	721	764	731

APPENDIX 8.4

8 x 8 MATRICES FOR EXPERIMENT 9.

Both hands compatible condition

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	MEANS
1	480	454	472	471	503	521	493	486	485
2	522	481	503	547	639	594	607	645	567
3	585	528	469	501	563	643	621	638	569
4	481	473	489	441	492	518	559	537	499
5	567	552	570	540	447	495	509	545	528
6	695	646	619	606	483	476	513	602	580
7	628	660	609	615	556	518	524	511	578
8	509	490	497	514	483	461	478	483	489
MEANS	558	536	529	529	521	528	538	556	536

Both hands incompatible condition

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	MEANS
1	625	654	701	670	830	710	723	752	708
2	706	580	590	655	706	640	652	669	650
3	676	622	571	611	613	675	707	702	647
4	645	611	694	606	649	657	747	721	666
5	708	714	679	695	582	692	686	632	674
6	704	739	732	668	669	602	637	635	673
7	696	701	730	667	660	633	571	632	661
8	793	760	791	785	688	711	692	632	732
MEANS	694	673	686	670	675	665	677	672	676

One hand compatible - one hand incompatible condition

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	MEANS
1	638	718	766	702	856	758	785	836	757
2	748	624	691	733	762	740	740	738	722
3	733	704	590	672	658	739	743	725	696
4	658	704	666	598	725	747	716	750	696
5	654	662	655	646	547	605	607	649	628
6	735	718	670	716	651	631	610	665	675
7	705	738	769	715	668	579	609	607	674
8	616	614	595	638	525	585	592	589	594
MEANS	686	685	675	678	674	673	675	695	680

APPENDIX 9.1

RELATED SAMPLES T TESTS FOR EXPERIMENT 10.

Comparing the RT to the repetition response with the RT to responses immediately adjacent to the repetition response for:

<u>Conditions without instructions for preparation</u>

(i) 2000 msec interstimulus interval
$t = 2.49$, d.f. = 5, n.s.

(ii) 1 msec interstimulus interval
$t = 1.47$, d.f. = 5, n.s.

<u>Conditions in which there was preparation for SH stimuli</u>

(i) 2000 msec interstimulus interval
$t = 1.50$, d.f. = 5, n.s.

(ii) 1 msec interstimulus interval
$t = 2.19$, d.f. = 5, n.s.

<u>Conditions in which there was preparation for OH stimuli</u>

(i) 2000 msec interstimulus interval
$t = 2.17$, d.f. = 5, n.s.

(ii) i msec interstimulus interval
$t < 1$ d.f. = 5

<u>Conditions in which there was preparation for the REP stimulus</u>

(i) 2000 msec interstimulus interval
$t = 5.05$, d.f. = 5, $P < .01$

(ii) 1 msec interstimulus interval
$t = 5.35$, d.f. = 5, $P < .01$

APPENDIX 9.2

ANALYSIS OF VARIANCE SUMMARY TABLES FOR EXPERIMENT 10.

Conditions without instructions for preparation

(i) 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	368938	5	73788			
2 (REP/SHNR/OH)	11767	2	5883.7	2/1x2	9.52	< .005
3 (Inner/Outer)	95584	1	95584	3/1x3	55.83	< .005
1x2	6162.6	10	618.26			
1x3	8559.8	5	1712.0			
2x3	1647.7	2	823.86	2x3/1x2x3	1.34	n.s.
1x2x3	6142.9	10	614.29			
TOTAL	498622	35				

(ii) 1 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	210958	5	42192			
2 (REP/SHNR/OH)	116184	2	58092	2/1x2	5.39	< .05
3 (Inner/Outer)	76729	1	76729	3/1x3	21.42	< .01
1x2	107681	10	10768			
1x3	17914	5	3582.7			
2x3	32797	2	16399	2x3/1x2x3	1.98	n.s.
1x2x3	82885	10	8288.5			
TOTAL	645148	35				

Conditions in which there was preparation for SH stimuli

(i) 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	142631	5	28526			
2 (REP/SHNR/OH)	129116	2	64558	2/1x2	13.94	<.005
3 (Inner/Outer)	42918	1	42918	3/1x3	4.70	n.s.
1x2	46323	10	4632.3			
1x3	45656	5	9131.2			
2x3	18598	2	9299.1	2x3/1x2x3	3.35	n.s.
1x2x3	27778	10	2777.8			
TOTAL	453020	35				

(ii) 1 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	186550	5	37310			
2 (REP/SHNR/OH)	277900	2	138950	2/1x2	39.81	<.005
3 (Inner/Outer)	32942	1	32942	3/1x3	7.30	<.05
1x2	34903	10	3490.3			
1x3	22562	5	4512.3			
2x3	43123	2	21562	2x3/1x2x3	7.47	<.025
1x2x3	28850	10	2885.0			
TOTAL	626830	35				

Conditions in which there was preparation for OH stimuli

(i) 2000 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	94200	5	18840			
2 (REP/SHNR/OH)	119041	2	59520	2/1x2	7.01	<.025
3 (Inner/Outer)	106493	1	106493	3/1x3	83.64	<.005
1x2	84906	10	8490.6			
1x3	6366.2	5	1273.2			
2x3	3955.1	2	1977.5	2x3/1x2x3	1.12	n.s.
1x2x3	17689	10	1768.9			
TOTAL	432650	35				

(ii) 1 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	285385	5	57077			
2 (REP/SHNR/OH)	18546	2	9272.9	2/1x2	2.54	n.s.
3 (Inner/Outer)	14480	1	14480	3/1x3	5.39	n.s.
1x2	36482	10	3648.2			
1x3	13435	5	2686.9			
2x3	19034	2	9517.2	2x3/1x2x3	1.64	n.s.
1x2x3	58096	10	5809.6			
TOTAL	445458	35				

Conditions in which there was preparation for the REP stimulus

(i) 2000 msec interstimulus

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	141765	5	28353			
2 (REP/SHNR/OH)	312217	2	156108	2/1x2	19.92	<.005
3 (Inner/Outer)	40535	1	40535	3/1x3	24.54	<.005
1x2	78362	10	7836.2			
1x3	8258.6	5	1651.7			
2x3	26408	2	13204	2x3/1x2x3	19.75	<.005
1x2x3	6687.1	10	668.71			
TOTAL	614233	35				

(ii) 1 msec interstimulus interval

Source	S.S.	d.f.	M.S.	Test	F	P
1 (subjects)	175676	5	35135			
2 (REP/SHNR/OH)	341180	2	170590	2/1x2	19.77	<.005
3 (Inner/Outer)	91103	1	91103	3/1x3	37.76	<.005
1x2	86299	10	8629.9			
1x3	12063	5	2412.6			
2x3	33153	2	16576	2x3/1x2x3	5.59	<.025
1x2x3	29631	10	2963.1			
TOTAL	769105	35				

APPENDIX 9.3

DUNCAN MULTIPLE RANGE TESTS FOR EXPERIMENT 10.

Comparing REP, SHNR and OH Inner and Outer mean reaction times

Any two treatment means not underscored by the same line are significantly different
Any two treatment means underscored by the same line are not significantly different

Conditions without instructions for preparation

(i) 2000 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges $P<.05$
MEANS		494	528	528	588	618	644	
A	494		34	34	94	124	150	$R_2 = 31.5$
B	528				60	90	116	$R_3 = 32.9$
C	528				60	90	116	$R_4 = 33.8$
D	588					30	56	$R_5 = 34.4$
E	618						26	$R_6 = 34.7$

A B C D E F

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	588	494
SHNR	618	528
OH	644	528

(ii) 1 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges $P<.05$
MEANS		586	616	619	640	736	829	
A	586		30	33	54	150	243	$R_2 = 117.1$
B	616			3	24	120	213	$R_3 = 122.4$
C	619				21	117	210	$R_4 = 125.5$
D	640					96	189	$R_5 = 127.5$
E	736						93	$R_6 = 128.8$

A B C D E F

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	616	586
SHNR	736	619
OH	829	640

Conditions in which there was preparation for SH stimuli

(i) 2000 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges F<.05
MEANS		470	471	521	548	580	700	
A	470		1	51	78	110	130	R_2 = 67.8
B	471			50	77	109	129	R_3 = 70.9
C	521				27	59	179	R_4 = 72.7
D	548					32	152	R_5 = 73.8
E	580						120	R_6 = 74.6

A B C D E F

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	521	470
SHNR	548	471
OH	700	580

(ii) 1 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges P<.05
MEANS		525	539	555	598	660	814	
A	525		14	30	73	135	289	R_2 = 69.1
B	539			16	59	121	275	R_3 = 72.2
C	555				43	105	259	R_4 = 74.0
D	598					62	216	R_5 = 75.2
E	660						154	R_6 = 76.0

A B C D E F

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	525	539
SHNR	598	555
OH	814	660

Conditions in which there was preparation for OH stimuli

(i) 2000 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges P<.05
MEANS		471	551	552	586	640	706	
A	471		80	81	115	169	235	R_2 = 54.1
B	551			1	35	89	155	R_3 = 56.5
C	552				34	88	154	R_4 = 58.0
D	586					54	120	R_5 = 58.9
E	640						66	R_6 = 59.5
		A	B	C	D	E	F	

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	640	552
SHNR	706	586
OH	551	471

(ii) 1 msec interstimulus interval

		A	B	C	D	E	F	shortest significant ranges P<.05
MEANS		590	602	603	624	662	734	
A	590		12	13	34	72	144	R_2 = 98.0
B	602			1	22	60	132	R_3 = 102.0
C	603				21	59	131	R_4 = 105.0
D	624					38	110	R_5 = 106.7
E	662						72	R_6 = 107.8
		A	B	C	D	E	F	

Table of the above mean reaction times

	Fingers	
	Inner	Outer
REP	603	590
SHNR	662	624
OH	734	602

Conditions in which there was preparation for REP stimuli

(i) 2000 msec interstimulus interval

		A	B	C	D	E	F
MEANS		406	423	523	572	575	715
A	406		17	117	166	169	309
B	423			100	149	152	292
C	523				49	52	192
D	572					3	143
E	575						140

shortest significant ranges P<.05

$R_2 = 33.3$
$R_3 = 34.8$
$R_4 = 35.7$
$R_5 = 36.2$
$R_6 = 36.6$

A B C D E F

Table of the above mean reaction times

	Fingers Inner	Outer
REP	423	406
SHNR	572	523
OH	715	575

(ii) 1 msec interstimulus interval

		A	B	C	D	E	F
MEANS		437	471	553	605	634	754
A	437		34	116	168	197	317
B	471			82	134	163	283
C	553				52	81	201
D	605					29	149
E	634						120

shortest significant ranges P<.05

$R_2 = 70.0$
$R_3 = 73.2$
$R_4 = 75.0$
$R_5 = 76.2$
$R_6 = 77.0$

A B C D E F

Table of the above mean reaction times

	Fingers Inner	Outer
REP	471	437
SHNR	634	553
OH	754	605

APPENDIX 9.4

8 x 8 MATRICES FOR EXPERIMENT 10.

Conditions without instructions for preparation

(i) 2000 msec interstimulus interval

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	520	556	528	584	549	549	555	481	540
2	633	583	601	626	643	614	581	647	616
3	644	565	556	671	621	651	637	598	618
4	493	525	497	467	505	514	522	545	509
5	522	509	537	550	490	507	543	519	522
6	639	684	621	656	627	609	630	641	638
7	678	676	699	651	618	614	603	570	639
8	487	573	517	523	519	538	526	496	522
MEANS	577	584	570	591	572	575	575	562	576

(ii) 1 msec interstimulus interval

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	542	575	739	499	588	607	587	554	586
2	690	622	628	673	824	785	818	817	732
3	797	674	616	812	763	787	888	806	768
4	686	625	610	536	670	639	687	707	645
5	674	652	692	698	669	650	737	603	672
6	894	916	837	825	710	653	783	786	801
7	787	863	833	814	703	631	572	932	767
8	582	674	604	607	627	514	559	594	595
MEANS	707	700	695	683	694	658	704	725	696

Conditions in which there was preparation for SH stimuli

(i) 2000 msec interstimulus interval

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	479	479	511	469	585	633	584	527	533
2	548	530	500	550	703	695	720	739	623
3	595	559	476	483	632	674	676	646	593
4	453	491	428	454	568	574	535	602	513
5	592	538	581	592	469	437	472	575	532
6	705	713	688	689	590	524	512	602	628
7	733	760	679	749	569	544	553	517	638
8	604	568	576	590	457	466	476	472	526
MEANS	589	580	555	572	572	568	566	578	573

(ii) 1 msec interstimulus interval

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	537	475	624	466	655	655	613	567	574
2	581	566	529	709	817	789	732	711	679
3	612	560	478	603	705	781	898	778	677
4	590	625	544	515	624	721	650	557	603
5	753	692	828	681	540	549	565	591	650
6	776	950	911	706	626	507	535	699	714
7	832	887	908	817	647	525	548	544	714
8	637	646	678	592	554	599	470	561	592
MEANS	665	675	688	636	646	641	626	626	650

Conditions in which there was preparation for DH stimuli

(i) 2000 msec interstimulus intervall

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	565	589	602	541	504	471	451	456	522
2	669	686	720	694	581	544	567	570	629
3	769	695	615	688	530	527	498	517	605
4	595	569	678	523	456	465	446	453	523
5	477	509	495	479	545	553	615	588	533
6	559	564	553	517	668	700	724	672	620
7	585	540	561	588	721	704	637	743	635
8	469	461	475	462	554	533	614	572	518
MEANS	586	577	587	562	570	562	569	571	573

(ii) 1 msec interstimulus interval

LAST RESPONSE

THIS RESPONSE	1	2	3	4	5	6	7	8	MEANS
1	557	574	622	587	609	529	505	562	568
2	718	674	574	773	635	678	804	687	693
3	742	765	550	565	682	728	832	689	694
4	779	683	616	570	587	713	544	669	645
5	697	546	668	576	607	556	654	673	622
6	774	816	636	764	694	548	587	743	695
7	657	787	760	795	653	622	640	619	692
8	541	620	663	596	612	580	546	624	598
MEANS	683	683	636	653	635	619	639	658	651

Conditions in which there was preparation for REP stimuli

(i) 2000 msec interstimulus interval

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	MEANS
1	409	484	588	481	622	615	583	541	540
2	537	416	521	598	619	775	728	721	614
3	669	506	434	494	621	633	665	700	590
4	606	503	461	360	453	562	520	595	508
5	590	616	610	547	438	490	539	540	546
6	767	776	695	678	583	419	527	664	639
7	768	754	774	765	618	564	421	582	656
8	567	626	609	536	474	577	534	416	542
MEANS	614	585	587	557	554	579	565	595	579

(ii) 1 msec interstimulus interval

THIS RESPONSE	LAST RESPONSE 1	2	3	4	5	6	7	8	MEANS
1	422	485	588	566	574	669	573	530	551
2	612	503	634	609	683	715	706	702	646
3	779	605	447	618	680	769	781	887	696
4	517	564	529	440	588	600	631	568	555
5	578	721	749	534	416	619	592	617	616
6	723	824	879	647	723	439	507	636	672
7	848	736	725	751	592	542	492	746	679
8	569	565	540	572	554	512	491	469	534
MEANS	644	625	636	592	601	608	597	644	619

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