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Schedule control of temporally based behaviour.

Cullen, Christopher Noel

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SCHEDULE CONTROL OF TEMPORALLY BASED BEHAVIOUR

A thesis submitted

by

CHRISTOPHER NOEL CULLEN, B.A.

to the University of Wales
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Department of Psychology,

University College of North Wales, Bangor.

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ERRATA

(i) Abstract, second page, line 4: for "press" read "presses"

(ii) Page 108, paragraph 3, line 4: for "longer" read "shorter"

(iii) Page 173, paragraph 2, lines 2-5: read "For B-1, B-2 and C-3 the overall response rate increased as the brief-stimulus conditions were changed, whereas..."

(iv) Page 226, paragraph 1, line 8: for "increase" read "decrease"

(v) Page 231, paragraph 3, line 4: for "the other 3 animals" read "F-3 and F-4"

(vi) Page 234, paragraph 1, lines 1-2: read "the response rate increased on changing to S^N, while it decreased in the case of F-1. Changing to S^P decreased the rate of F-1 and F-3, an effect which was reversible".

The science of behaviour is too young and unstructured at this point to progress merely by the accumulation of facts or by the elaboration of great theoretical systems. We are at a stage where progress is made by the clarification of methodological issues and the re-organisation of conceptual issues. An understanding of these issues and an appreciation of how they change are critically important because it is they rather than the great theoretical structures that guide our research efforts.

(Robert C. Bolles, Theory of Motivation, 1967).

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ABSTRACT

Some of the main characteristics of second-order schedules were investigated.

In Section I, the component schedules were (drl 10-sec) and (drl 20-sec). These were held constant and the parameters of the overall schedule were varied. In several important respects, the component schedule functioned in the same way as a simple operant is known to function with regard to the overall schedule. However, varying the value of the overall schedule also resulted in systematic changes in the response patterning within the component.

Three studies were presented in Section II in which the effects of the parameters of the component schedule on overall schedule control were investigated. In one experiment, the lever presses which did not count as responses were found to have an important function on a DRL 20-sec schedule. The second experiment examined the direct effect on fixed-interval control of changing the component schedule from (drl 10-sec) to (drl 20-sec) and vice versa. The final report is of the effect of changing from DRL 5-sec or DRL 10-sec to a DRL 30-sec (drl ^{x}-sec) schedule. In all these cases, the nature of the operant was an important factor in determining the overall schedule control.

Erratum (i)

In Section III, five experiments into the effects of brief paired (S^P) and non-paired (S^N) stimuli were presented. Typical DRL patterning was evident under the tandem schedules, and this was improved on adding S^N. The temporal distribution was sharpened even further on adding S^P. More detailed analysis revealed that S^N and S^P acted primarily on different aspects of the behaviour. The main effect of adding S^N was to sharpen the temporal distribution of those responses following the completion of a non-reinforced component, whereas the effect of changing to S^P was to increase the postreinforcement pause.

These effects are accounted for by a view which holds that the controlling effect of a stimulus event is increased by increasing the number of stimulus elements present.

INTRODUCTION

CHAPTER 1

INTRODUCTION

Early investigations of behavioural phenomena. were largely concerned with the examination of very large units of behaviour, such as the performance of rats in escaping from puzzle boxes (Thorndike, 1911), or the performance of humans in dealing with lists of nonsense syllables (Ebbinghaus, 1885). These experiments were important in establishing the study of behaviour as a respectable scientific enterprise, but the emphasis soon shifted to the rigorous examination of much smaller units of behaviour.

I.P. Pavlov is generally accepted as the 'father' of the experimental analysis of behaviour, influencing as he did both J.B. Watson (cf. Watson and Raynor, 1920) and B.F. Skinner (Skinner, 1972), and it was Pavlov who brought the study of small behavioural units to the attention of the scientific community (Pavlov, 1927). Some few years later, Skinner (1935) introduced the concept of the operant, a move which was to determine the course of development of experimental psychology for the next thirty years.

Two important consequences of the introduction of the concept of the operant may be identified. One is that nearly all experimental work up to the early sixties was concentrated on simple operants such as lever presses and key pecks, although there is nothing inherent in the nature of operants that they should be simple units. Indeed, a large amount of Skinner's own writing has been concerned with the analysis of complex operant classes (Skinner, 1953; 1957).

A second consequence is that the rationale behind the term has been much discussed and examined in relation to both its use as a unit of behaviour (cf. Catania, 1973 a), and to its 'circularity' in definition (cf. Schick, 1971).

It is not within the scope of the present thesis to examine the problems of circularity, although the question of the usefulness as a unit of behaviour will be discussed in later Sections.

The original formulation of the notion of an operant (Skinner, 1935; 1938) centred on its usefulness in demonstrating dynamic and functional relationships between behaviour and environment, and on its convenience of measurement. It follows, then, that any segment of behaviour is a member of an operant class if it possesses the property upon which reinforcement is contingent, and if systematic functional relationships between that operant and its environment can be demonstrated.

This is the view taken in the present thesis and is in accord with the views of the majority of writers on the subject (cf. Catania, 1973 a ; Gilbert, 1958; Schick, 1971; Sheldon, 1974; Skinner, 1938; 1953; Staddon, 1967).

A germinal paper by Findley (1962) was partly instrumental in changing the previously mentioned experimental emphasis away from the study of small units, and towards the study of larger, more complex units of behaviour, while still remaining within the tradition of 'operant psychology'. This movement led directly to the study of second-order schedules of reinforcement, and it is within this area that the experiments reported in this thesis were carried out.

A second-order schedule is:

> "...a schedule which treats a pattern of behaviour engendered by a schedule contingency as a unitary response that is itself reinforced according to some schedule of reinforcement". (Kelleher, 1966 b , p.476).

It can be seen, then, that second-order schedules are concerned, by definition, with complex operants, yet in the first few years of their use this fact was not emphasised. Instead, these schedules were used almost solely to investigate the phenomenon of conditioned reinforcement. The present thesis is partly an attempt to integrate the fields of investigation into complex operants and into conditioned reinforcement. This is achieved by placing much more emphasis than is usual on the complex operant aspect of the second-order schedules which have been used here.

The study of second-order schedules, however, is not the only area of investigation of complex behaviour, and there have arisen important confusions in terminology. Some examples will prove useful here.

On a second-order schedule, a particular reinforcement schedule (say fixed-interval 30 sec (FI 30-sec)) is treated as a unitary response and reinforced according to another schedule of reinforcement (say fixed-ratio 5 (FR 5)). The FI 30-sec schedule is referred to as the <u>component</u>, while the FR5 schedule is referred to as the <u>overall</u> schedule. The second-order schedule may thus be denoted as:

FR5(FI 30-sec)

In this example, each time the subject satisfied the FI 30-sec contingency, the FR counter is advanced by one. When it has advanced five times, reinforcement is given. This schedule, however, may also be called a tandem schedule, which is defined by Ferster and Skinner (1957) as a schedule in which a single reinforcement is programmed by two or more schedules acting in succession without correlated stimuli.

Using the notation common to tandem schedules, this example would become:

tandem FI 30-sec FI 30-sec FI 30-sec FI 30-sec FI 30-sec

and, consequently, the term 'tandem' has come to be a convenient shorthand for describing those second-order schedules where the only stimulus presented is the reinforcer (cf. Stubbs, 1971). However, not all second-order schedules of this basic type are tandem schedules in the sense of Ferster and Skinner (1957), since the arrangement of schedules acting in succession applies only to second-order schedules with overall ratio schedules. An example of a second-order schedule without correlated stimuli which would not be described as a tandem schedule by Ferster and Skinner (1957) is:

FI 2-min(FR 10)

The confusion is mentioned here since it is the intention of the present writer to use the term 'tandem' in this thesis in its wider sense, and not as strictly defined by Ferster and Skinner (1957).

Traditionally, of interest in second-order schedules has been the effects of brief stimulus manipulations on the pattern of responding within the component schedule. One of these manipulations has been the presentation of a brief exteroceptive stimulus on the completion of each component except the one terminated by reinforcement. This is referred to as the <u>non-paired (S^N)</u> condition, and is represented as:

$$FR5(FI\ 30\text{-sec}:\ S^N)$$

When all components are followed by the brief stimulus, then the <u>paired (S^P)</u> condition is in effect. It is represented as:

$$FR5(FI\ 30\text{-sec}:\ S^P)$$

Having recognised the usefulness of second-order schedules in the study of complex response classes, one is then led to consider questions such as; do complex operants come under schedule control in the same way as simpler operants?; how do the characteristics of the operant change, both with changes in the overall schedule, and with brief stimulus manipulations?; is there an interaction between the control exerted by the overall and the component schedules?; and what are the most suitable dependent variables to describe any changes?

The present thesis is part of an answer to these questions. It is hoped to extend the area of second-order schedule research to encompass the study of complex operants, and thus to help towards the establishment of an understanding of the control of complex behaviour.

A REVIEW OF THE LITERATURE OF SECOND-ORDER SCHEDULES

CHAPTER 2

The literature on second-order schedules has been concerned largely with the problem of conditioned reinforcement, in a situation where the behaviour chain is maintained by the presentation of a primary reinforcer.

> "Second order schedules permit the study of patterns of behaviour controlled by the scheduling of a conditioned reinforcer in a situation where responding is ultimately maintained by the scheduling of a primary reinforcer". (Marr, 1969, pp.37-38).

Recently, however, the correspondence between second-order schedules and schedules of complex operants has been made explicit (cf. Bigelow, 1969, 1971; Boren, 1973), and the present review will concentrate on this aspect of second-order schedules.

A fully comprehensive review of all aspects of second-order schedules would necessarily involve the literature on conditioned reinforcement, and the literature of complex response classes. The former includes, as well as second-order schedules, experiments on chaining and similar complex schedules (cf. Kelleher, 1966 a ; Kelleher and Gollub, 1962); experiments concerned with the efficacy of establishing stimuli as conditioned reinforcers by pairing them with food (cf. Schuster, 1969; Zimmerman, 1969); schedules of token reinforcement (cf. Kelleher, 1966 a ; Waddell, Leander, Webbe, and Malagodi, 1972); and observing response studies (cf. Hendry, 1969; Jenkins and Boakes, 1973).

The latter series of experiments is potentially very large, since even a simple schedule may be considered as a unitary response maintained under a fixed-ratio schedule with a value of one (cf. footnote in Staddon, 1967, p.387). The more common complex operants which have been studied include matching-to-sample (cf. Cumming and Berryman, 1965; Ferster, 1958, 1960); verbal behaviour (cf. Salzinger, 1973; Skinner, 1957); interresponse times (cf. Reynolds and McCleod, 1970);

social responses such as co-operation (cf. Hake and Vukelich, 1972) and imitation (cf. Peterson, 1968); and conditional discrimination (cf. Stubbs and Galloway, 1970).

The present review, then, will be examining the second-order schedule literature with the purpose of ascertaining the effects of experimental manipulations on the patterning and control of the operant classes concerned.

Second-order schedules may conveniently be classified in terms of the component schedule used.

Fixed-interval components

A fixed-interval (FI) schedule is in effect when the first occurrence of a response after a specified period of time since some event (usually reinforcement) is followed by the presentation of reinforcement. All other responses have no scheduled consequence. FI components have been used more extensively than any other schedule, and this group of experiments has provided a very large proportion of our present information about second-order schedules.

Stubbs (1971), in an extensive series of experiments, reinforced FI components according to fixed-ratio (FR), variable-ratio (VR), FI, and variable-interval (VI) schedules, and reached the following conclusions:

(i) brief stimulus presentations engendered patterns of responding similar to those engendered by food.

(ii) there were no differences apparent in performance when the brief stimulus was paired with food, and when it was not.

(iii) this effect was not changed by making the brief stimulus presentations response-independent.

(iv) the parameters of the brief stimulus were important in determining the patterning of responses.

There are two important aspects of this experiment. Firstly, he found that no difference existed between the effects of paired (S^P) and non-paired (S^N) stimulus presentations. This conclusion was contrary to all of the previous literature, which had shown that the S^P condition maintained response patterning, whereas the S^N condition either did not, or maintained poor patterning (see below). Secondly, Stubbs pointed to some important methodological faults in previous experiments which might account for this discrepancy.

In those sections of Stubbs' (1971) experiments with FI components, he used FI values of 40-sec, 60-sec, and 64-sec, reinforced according to VI 360-sec, FI 300-sec, FI 600-sec, VR2, VR4, FR2, and FR4. His subjects were pigeons, and reinforcement was 4-sec access to mixed grain. The dependent variables he chose to analyse were response rates and the patterning of responses within components. The latter measures were the Index of Curvature (Fry, Kelleher, and Cook, 1960) - which is a statistic estimating the rate of change of response rate within a component - and the response rate over each quarter of the interval. Brief stimulus presentations consisted of a change in keylight colour from red to white lasting 0.75 sec, plus illumination of the houselight for the same period of time. He presented tandem, S^N, and S^P conditions in different orders for different birds.

Stubbs found that there was little or no patterning evident when the tandem condition was in operation. When either the S^N or S^P condition was in effect, patterning was evident within the component. The patterning was an increase in response rates across quarters of each FI component.

In the case of FR (FI) and VR (FI), he presented the rates in each quarter for the components immediately following food separately. Here, he showed that there was within-component patterning regardless of brief stimulus conditions, although the rates were higher in the initial component of FR (FI) under brief stimulus conditions than under comparable tandem conditions. Index of Curvature measures, for those components not immediately following food, showed little patterning under tandem conditions, but considerable patterning under brief stimulus conditions. Although there were considerable differences in Index of Curvature between S^N and S^P, they were not systematic (Fig. 5). There were also non-systematic differences in total response rates between S^N and S^P in the FR (FI) and VR (FI) experiments (Fig. 4). (It might be worth pointing out that rate under S^N was higher than that under S^P for 3 of Stubbs' 4 birds, and these differences were of the same magnitude as the differences he reported between the tandem and brief stimulus conditions).

Stubbs considered these results not to be affected by variables such as:

(i) the prior history of the bird

(ii) indirect pairing of the brief stimulus and food (many other experimenters have used a flash of the magazine light as S^P)

(iii) the particular class of stimuli

(iv) the experimental 'hardware'

(v) the overall schedule of reinforcement or rate of reinforcement

The methodology of Stubbs' experiments may be criticised on points such as the very short exposure he gave under each condition (often as little as 10 sessions), but he controlled one important variable which very few other experiments have. The same physical stimulus was used as S^N and S^P.

Malagodi, De Weese, and Johnston (1973) submitted their paper to the Journal of the Experimental Analysis of Behaviour before the publication of Stubbs (1971). One part of their series of experiments was concerned with a comparison of S^N and S^P under FR (FI) and FI (FI).

They reported little patterning under the S^N condition as opposed to the S^P condition. They used a tone and change in key colour both lasting 0.25 sec as S^N, but a feeder flash of 0.25 sec duration as S^P, and consequently they revised their Discussion to include Stubbs' criticism of this type of procedure, which might be presenting a more 'salient' S^P.

Stubbs and Cohen (1972) have added to Stubbs' (1971) finding by demonstrating no difference in patterning within FI components; this was regardless of the method of scheduling S^N and S^P. They varied the temporal relation between the brief stimulus and the reinforcer on VI (FI) schedules, and found little difference between the different conditions. They did report, however, that a blackout as a brief stimulus maintained less patterning than other stimuli, which provides additional support for a 'stimulus saliency' effect, at least with pigeons as subjects.

The term 'second-order schedule' was first used by Kelleher (1966 b). His original experiment was a comparison of S^N and S^P on a FR (FI) schedule. The rate of reinforcement was unusually low in these experiments - a maximum of one reinforcement each hour - but very clear differences were reported between S^N and S^P. The schedules he used were FR 15 (FI 4-min) and FR 30(FI 2-min). When S^N was a brief darkening of the response key, there was a very clear difference in response patterning from the pattern maintained by S^P (which was a white keylight flash). When S^N was a red keylight flash, there was much less of a difference. This ties in with the findings of Stubbs (1971) and Stubbs and Cohen (1972) reviewed above.

The method of analysis used by Kelleher (1966 b) is interesting, since he presented the mean response rate for each quarter of the FI components. These means were compiled in the case of FR 30 (FI 2-min), for example, by obtaining the rate in the first 30 sec of the first component, the rate in the first 30 sec of the second component, and so on for 30 components. Then, the rates were obtained for the second 30-sec of each of the 30 components, and so on until there were 4 rates, which were the means for 30 intervals. This procedure ignored the possibility of lawful changes in behaviour as reinforcement is approached, although our knowledge of FR schedules indicates that this would be so (cf. Section I below). It is unlikely that the mean response rate of the first quarter of the FI would be representative of either the rate in the first quarter of the component directly following reinforcement, or the one directly preceeding reinforcement.

Marr and de Lorge (1966), reported in Marr (1969), compared S^N and S^P using a within-session design. They used a multiple schedule, which consisted of two or more alternating schedules of reinforcement, with different stimuli present during each. In the presence of a cross on the key, FR 10(FI 2-min: S^P) was in effect. When there was a circle on the key, FR 10(FI 2-min: S^N) was in effect. S^N was a brief tone, while S^P was a brief flash of light, and they found little or no patterning under the S^N condition Marr (1969) did not give many details, but the different stimuli used as S^N and S^P, and the analysis in terms of overall response rates and presentation of cumulative records, makes interpretation difficult.

de Lorge (1967) used a FI 18-min (FI 3-min) schedule, with S^N as a 0.5 sec flash of green keylight, and S^P as a 0.5 sec flash of yellow keylight. Patterning was produced by S^P, but was also evident in some cases under the S^N condition. A complication with this experiment was that his single bird had previously been exposed for 130 days to VI 90-sec in a red-green discrimination task. It might have been the case, therefore, that the S^N was a powerful discriminative stimulus before the commencement of the second-order schedule study. (Stubbs (1971) specifically argued against this type of 'history' effect, and de Lorge (1971) demonstrated that previous history of conditioning was unimportant, at least with some types of second-order schedules (see below)). Colour preferences may have played a role (Morgan, Lea, and Nicholas 1975).

In a later experiment, de Lorge (1969) used a multiple schedule with VR 10 (FI) components to demonstrate that S^P (hopper light) produced more patterning than did S^N (a red keylight flash). S^P also controlled higher overall response rates than did S^N.

Byrd and Marr (1969) reported a series of experiments comparing S^N and S^P. These experiments involved VR (FI) schedules, but additional stimuli were involved because the experimenters were concerned to examine the effect of changing or not changing the stimulus present on the key during successive components, as well as the effect of brief stimulus presentations. They found that S^P maintained patterning, but S^N didn't. In all cases, the tandem schedule maintained the highest overall response rates, but when the key-stimulus was unchanged during successive components (a normal second-order schedule), then S^N maintained higher rates than did S^P, for all birds. This finding is the same as that reported by Stubbs (1971) for 3 of his 4 birds. Although S^P was a 1-sec feeder flash, and S^N was a 1-sec change in the keylight colour to red in the Byrd and Marr (1969) study, the rate differences were consistent enough to warrant further investigation.

The differnces in overall response rate between S^N and S^P mentioned by Byrd and Marr (1969) and by Stubbs (1971) might possibly conceal differences in response patterning which would not be shown by 'crude' methods of analysis. Dukich and Lee (1973) compared the measures of response patterning normally used in FI schedules, and concluded that

> "...no single measure adequately described or specified all the changes in FI patterning ... variability from interval to interval... is an important factor in considering the adequacy of a measure". (p.289)

They recommended that (i) post-stimulus pause and (ii) running rate were the two measures that most adequately described FI behaviour, but none of the second-order schedules with FI components reviewed here have used these measures.

With the exception of Stubbs (1971) and Stubbs and Cohen (1972), all experiments concerned with a comparison of S^N and S^P have reported little or no patterning in the S^N condition. There are, however, several studies where the concern has been with matters other than a comparison of S^N and S^P, but where response patterning in the S^N condition has been reported. Among these are the reinforcement omission procedures of Neuringer and Chung (1967) and Staddon and Innis (1969).

Interpretation of the Neuringer and Chung (1967) experiment is difficult due to the unusually small FI component - FI 5-sec - and due also to the fact that the FI had to be initiated by a response. In this VI 1-min (tand FR1 FI 5-sec: S^N) schedule patterning was maintained within the component. S^N was a brief blackout, which Kelleher (1966 (b)) reported to be much less effective than other stimuli in maintaining response patterning.

Staddon and Innis (1969) ran an even more complicated schedule, with odd-numbered FI components having the probability of 0.5 of being followed by a brief blackout. They report patterning in all components, including those followed by the non-paired blackout.

Zeiler (1972) used a VR (FI) schedule in a reinforcement omission experiment, with a 4-sec blackout as S^N, and he obtained patterning in all components.

From these experiments, it seems, therefore, that patterning may be maintained by S^N, in at least some cases, with FI components. Furthermore, the nature of the brief stimulus may be a relevant variable. Stubbs and Silverman (1972), for example, used a brief shock as the stimulus on VI 240-sec (FI 60-sec) and obtained the same effect as Stubbs (1971). There was, however, a lot of variability in their data.

Cohen, Hughes and Stubbs (1973) reinforced the responses of pigeons on VI 240-sec (FI 48-sec), and varied the duration of a preceding, non-overlapping S^P. They claimed improved patterning within components, as shown by Index of Curvature measures, as the duration of the brief stimulus was increased from 0.5 sec to 2.0 sec to 8.0 sec. From the data shown in this paper, however, although there was an increase in Index of Curvature as S^P was increased in duration from 0.5 sec to 2.0 sec, the difference between 2.0 sec and 8.0 sec was very small for one bird, and non-existant for the other. These results corroborated those of Staddon and Innis (1969), who manipulated blackout duration, but not those of Neuringer and Chung (1967), who obtained no effect of stimulus duration on VI (FI: S^N). Cohen et al. (1973) explain this disagreement as the result of different methods of analysis.

An important point to arise from examination of second-order schedules with FI components has been the relevance of a detailed analysis of component behaviour to the question of possible differences in effect between S^N and S^P. Very few other general conclusions are possible because the contradictions within the literature are exacerbated by lack of such detailed analyses.

Fixed-ratio components

A fixed-ratio (FR) schedule requires a specified number of responses to be emitted for a single reinforcement. No time-limit is placed on the completion of these responses.

Studies in which FR components have been used to compare S^N and S^P are few, which is surprising since FR behaviour is generally thought of as stable and easily quantifiable (cf. Felton and Lyon, 1966; Ferster and Skinner, 1957).

Stubbs (1971) used pigeons as subjects on a multiple [FR 4(FR 40: S^N)] [FR 4(FR 40)], which was changed after 20 sessions to multiple [FR 4(FR 40: S^P)] [FR 4(FR 40)]. The brief stimulus in both cases was a change in the keylight colour and a houselight flash, both 1 sec in duration. A further group of 3 birds were ran on FR 4(FR 20: S^N) for 20 sessions, FR 4 (FR 20: S^P) for 10 sessions, changed back to FR 4(FR 20: S^N) for a further 10 sessions, and finally onto FR 4(FR 20) for 20 sessions.

To detect patterning, Stubbs examined response rates in each eighth of the components. For 1 of the 3 birds on the multiple schedule, there was a clear difference, shown by this measure, between the tandem and the brief stimulus conditions. One bird showed no difference at all, while for the remaining subject there was a small effect. For the 2 birds who showed the effect, total rates were higher under the brief stimulus conditions than under the tandem condition. This effect was reversed with the other bird.

In the case of the second group of pigeons, only one showed patterning of the break-and-run type. Whether or not patterning occurred, there were few differences between the brief stimulus and tandem conditions, and between the S^N and S^P conditions.

In these two experiments, there was little evidence of any difference between the brief stimulus conditions mainly because there was little patterning anyway. Stubbs (1971) pointed to this weakness, and suggested that more detailed recording and analysis might reveal some effects. This is a suggestion put forward elsewhere in this thesis for second-order schedules as a whole.

Moreover, these two experiments are the only ones published explicitly comparing S^N and S^P with FR components.

Thomas and Stubbs (1966) increased overall response rates above those of a comparable tandem schedule by the imposition of S^P onto a FR (FR) schedule. They also found 'typical' FR patterning, as did Findley and Brady (1965) who used chimpanzee subjects on FR 10 (FR 400: S^P). These workers used a mixed schedule, which is the alternation of two or more schedules of reinforcement, without the accompaniment of correlated stimuli. They alternated FR 4000 with FR 10 (FR 400: S^P), and found shorter pauses and working times, and a strong preference for second-order schedules. Both of the schedules, however, required the completion of 4000 responses for reinforcement.

Second-order FR performance was analysed in detail and compared with simple FR behaviour by Davison (1969). His experiment was unique in two respects. First, he used rats as subjects, whereas most workers have used pigeons. Second, his method of analysis included a detailed examination, in terms of interresponse times (IRTs), of the component behaviour. The schedules he used were FR 6: S^P; FR 6 (FR 6: S^P); and FI 1-min (FR 6: S^P). The brief stimulus was a time-out of minimum duration 5-sec. Any responses made during this period re-started the time-out.

The pattern of responding under FR 6: S^P was an initially long IRT followed by five shorter IRTs, the last one occasionally being longer than the others due to the rat investigating the food area. Under FI 1-min (FR 6: S^P), the latencies of components decreasing during the interval, a finding also reported by Kelleher (1966 a). A similar result was obtained for the FR 6(FR6:S^P) schedule, with a decreasing latency for successive components. On both second-order schedules, Davison (1969) reported a decrease in IRTs within components as reinforcement was approached.

For the purposes of the present review, these analyses seem important in two respects. First they demonstrate 'typical' control by the overall schedule, and 'typical' FR behaviour within components. Second, the mode of analysis is very similar to that used in this thesis, and is one which the present author considers desirable in any analysis of second-order schedules.

Blackman, Thomas, and Bond (1970) used a procedure related to that of Davison (1969) in comparing the behaviour of pigeons under FR 1(FR 10: S^P) and FR 1(FR 10). They were concerned with demonstrating the comparability of simple units of behaviour, such as key-pecks, with the sequences of schedule-controlled behaviour treated as unitary responses in second-order schedules.

Shull, Guilkey, and Witty (1972) reinforced the responding of pigeons according to a FI(FR: S^P), varying both the FI and FR parameters. S^P was a 0.7 sec key darkening, and maintained patterned FR behaviour consisting of a pause after reinforcement followed by a response 'run' to the next S^P or to reinforcement. For a particular FI value, the pauses increased slightly on changing the FR value from 10 to 20. The post-reinforcement pause was a function of the FI parameters for all FR values.

Lee and Gollub (1971) had pigeons responding on different values of a FR(FR: S^P) schedule, with the overall number of responses needed for reinforcement held constant, and they also found that a brief stimulus occasionally paired with reinforcement maintained within-component FR behaviour.

As in the case of second-order schedules with FI components, it has apparently been possible to maintain FR components using S^N. Kelleher, Fry, and Cook (1964) reinforced the responding of squirrel monkeys according to a DRL(FR 200: S^N). The overall schedule in this case specified the minimum time to be taken to complete the 200 responses. If less time was taken, then there followed a 0.5 sec blackout (S^N). For DRL 1-min and DRL 2-min the subjects were responding appropriately within a very short training time.

Ferster and Skinner (1957) reported an experiment where they occasionally omitted reinforcement and substituted a brief time-out on FR 40, using pigeons as subjects. The analysis of this experiment, and that of other reinforcement omission experiments using FR schedules (Davenport and Thompson, 1965; McMillan, 1971), is, however, difficult to incorporate meaningfully into the sphere of second-order schedule research.

The main conclusion to be drawn from those studies reviewed here with FR components is that there is not sufficient data to compare the effects of S^N and S^P, although it is clear that FR behaviour may be brought under schedule control in second-order schedules.

Variable-interval components

A variable-interval (VI) schedule specifies that reinforcement will be provided for the first response to occur after n sec from the preceding reinforcement. There are several values of n and the average value of n is the schedule parameter.

There is only one published second-order schedule with VI components. de Lorge (1971) used pigeons in a within-session design in a comparison of S^N and S^P. A two-unit multiple schedule was in operation, represented as mult [FR 5(VI 1-min: S^P)] [FR 5(VI 1-min: S^N)] . The brief stimuli were red and white illuminations of the food hopper, but since these were reversed in one stage of the experiment, obtaining a reversal in effect, the criticism of Stubbs (1971) concerning the 'saliency' of the hopper light and its use as S^P, does not seem to apply.

de Lorge (1971) examined postreinforcement pause and running rates, and found that S^P maintained higher running rates and shorter postreinforcement pauses than did S^N. He also used a mult [FR 5(VI 1-min)] [FR 5 (VI 1-min: S^P)] schedule, and showed that the postreinforcement pause was longer under the tandem condition, and that the running rate was higher under S^P than under the tandem condition. Also given in this paper was the response rate in each successive VI component - an analysis akin to that of Davidson (1969). This analysis showed that the rate in each component was always higher under S^P than S^N, and the rate increased with successive components. This last result showed that the overall FR schedule was exerting control.

Reversing the stimulus pairings led to a reversal of the relative response rates and patterns of responding for each stimulus - a finding which demonstrates that the effect was not due to a previous history of reinforcement in the presence of the particular stimulus. The postreinforcement pause findings are the clearest reported, and demonstrate that the brief stimuli not only had an effect on the component behaviour, but also on the overall schedule control - a point rarely made.

Differential-reinforcement-of-low-rate components

A differential-reinforcement-of-low-rate (DRL) schedule requires spacing of responses; the time interval between response n and response n + 1 (the IRT) must equal or exceed some specified value if response n + 1 is to be reinforced.

There have been few studies using the DRL schedule as a component, and all the second-order schedules described later in this thesis have been investigated partly to rectify this omission.

Thomas and Stubbs (1967) compared the performance of 3 pigeons under tandem, chain, and S^P schedules, the section of major interest here being their comparison of FR 3(drl) and FR 3(drl: S^P). They found that S^P engendered higher response rates in the early components than did the tandem schedule. Of major interest here, however, is the distribution of the responses in time (cf. Kramer and Rilling, 1970; Wilson and Keller, 1953).

DRL 12-sec was used for 1 bird, and DRL 8-sec for 2 birds. S^P was a magazine light flash of 0.3 sec duration. The major difference between the tandem and S^P condition was in the first component, where S^P engendered a larger percentage of short IRTs and a smaller percentage of long IRTs than the tandem condition. The second and third components were very similar in both schedules. For the tandem schedule, the amount of time spent in each component was least in the first, and most in the last component. This shows that the animal was making more 'mistakes' in the later components, whereas the IRTs made just after reinforcement were long enough to satisfy the DRL criterion. This effect was not so marked under S^P, but was still present.

Trumbule, Switalski, and Gilbard (1968) obtained results in accord with those of Thomas and Stubbs (1967). They used a chain DRL 9-sec DRL 9-sec DRL 9-sec and found a decrease in long IRTs as reinforcement approached.

Trumbule et al (1968) used rats as subjects, as did Bigelow (1971) who also found that the mean IRT decreased through successive components under three different FR (drl 4.5-sec: S^P) schedules. The experiment to be reported in Chapter 3 of this thesis is concerned with the detailed analysis of FR(drl) behaviour, and Bigelow's (1971) experiment is reviewed in greater detail there.

Bigelow (1969) compared the performance of rats under FR(drl 10-sec) and FR(drl 10-sec: S^P) schedules. The S^P was 0.5 sec of houselight with a light over the lever turned on at the same time. The FR values used were 2, 4, and 5. He found that S^P maintained a higher rate of 'correct' responses, i.e. IRTs which satisfied the DRL requirement, than did the tandem condition. When S^P was removed, the total response rate declined. He also found that there weremore very short IRTs under the S^P condition, a finding also reported by Thomas and Stubbs (1967).

de Lorge (1969) has reported the only study to compare tandem, S^N, and S^P conditions. He used a multiple schedule with FR(drl) components and compared tandem and S^P, S^N and S^P, S^P and reinforcement, in different phases of the experiment. S^P was illumination of the hopper light for 0.5 sec, and S^N was illumination of the hopper by a red light for 0.5 sec. He showed that S^P was more effective than S^N in producing high response rates, and also that S^P produced higher rates than did the tandem condition. When S^P was compared with the reinforcer, the food maintained higher rates, although this portion of the schedule tended to last longer, so it might have been the case that food actually exerted less control than S^P. Cumulative records suggested longer postreinforcement pauses under the tandem condition. As in the experiments of Bigelow

(1971), Thomas and Stubbs (1967), and Trumbule et al. (1968), response rates increased as the terminal component approached.

de Lorge's (1969) data were presented in terms of response rates. In general, analyses of DRL schedules in terms of the relative frequency distributions of IRTs yields information not readily available in rate data. The experiments presented in later chapters of this thesis show that de Lorge's (1969) conclusion that DRL is insensitive to brief stimulus manipulations is erroneous, based as it is on a study of overall response rates.

There exists a field of study in the experimental analysis of behaviour described as IRT reinforcement (cf. Anger, 1956; 1973; Mallott and Cumming, 1964; Reynolds and McCleod, 1970; Wilkie and Pear, 1972). Anger (1956), for example, has reinforced IRTs greater than 40 sec according to a VI 2.5-min schedule, i.e. VI 2.5-min(drl 40-sec). These experiments are interesting since they demonstrate quite clearly that temporal control of responding is possible when only a small percentage of the spaced responses are reinforced. They also show that temporally spaced responses may be treated as unitary responses and reinforced according to some other schedule of reinforcement. However, these schedules are not generally studied in order to answer the type of question posed in this thesis, and the manipulations made and methods of analysis used are such that there is no advantage to be gained by including them in this review.

Explanations for brief stimulus effects

The literature available at present does not provide enough evidence to determine the necessary and sufficient conditions under which a brief stimulus will influence behaviour under a second-order schedule, nor what that effect will be. A summary of the main findings of studies reviewed here include:

(i) S^P maintains higher response rates, and better patterning, than does S^N (cf. Byrd and Marr, 1969; de Lorge, 1967; 1969; 1971; Kelleher (1966 b); Malagodi et al. 1973; Marr, 1969; Stubbs, 1969)

(ii) S^P maintains similar behaviour to that maintained by S^N (cf. Stubbs, 1971; Stubbs and Cohen, 1972).

(iii) Brief stimuli maintain higher overall response rates than do comparable tandem situations (cf. de Lorge, 1967; 1969; 1971; Findley and Brady, 1965; Marr, 1969; Neuringer, 1968; Neuringer and Chung, 1967; Stubbs, 1969; Thomas and Stubbs, 1966; 1967).

(iv) Tandem schedules maintain higher rates than do brief stimulus schedules (cf. Byrd and Marr, 1969; Stubbs, 1971).

(v) Brief stimulus conditions engender shorter postreinforcement pauses and higher initial component rates than do comparable tandem schedules (cf. Byrd and Marr, 1969; de Lorge, 1971; Findley and Brady, 1965; Kelleher, 1966 b ; Malagodi et al. 1973; Stubbs, 1969; 1971; Thomas and Stubbs, 1967; 1969).

These inconsistencies point clearly to the necessity of a detailed functional analysis of second-order schedules, with the aim of (a) identifying the effects of stimulus interventions in particular classes of second-order schedules, and (b) determining the necessary and sufficient conditions for these effects.

The discussion of stimulus effects in second-order schedules has so far been under the head of

1. Conditioned reinforcement, and
2. Discriminative stimulus effects

1. Conditioned reinforcement

A conditioned reinforcer is a stimulus which has acquired reinforcing properties by virtue of close temporal pairing with a primary reinforcer, such as food (cf. Kelleher and Gollub, 1962). At a simple level, this concept has served well to explain brief stimulus effects in those second-order schedules where S^P maintains patterning, but S^N and tandem conditions do not. However, where S^N may be shown to maintain component behaviour (cf. Neuringer and Chung, 1967; Stubbs, 1971), in order to use the notion of conditioned reinforcement one has to suppose there is 'indirect' pairing, mediated, perhaps, by the behaviour in the final component.

It is commonly assumed, however, that any stimulus which can be shown to increase the likelihood of the behaviour upon which it is contingent is by definition, a reinforcer (cf. Kelleher and Morse, 1968; Nevin, 1973). It follows, then, that if any S^N maintains behaviour, we may speak of that stimulus as a reinforcer. We may still use the term "conditioned reinforcer" if we wish to make a distinction between those stimuli which acquire reinforcing properties through association in particular contingency arrangements, and those stimuli which appear to always possess that property, but, as Schoenfeld (1969) has suggested, even this distinction may be of no real use.

One of the advantages of this type of explanation is that it allows us to fit the brief stimulus effects into a neat framework of reinforcers and punishers, positive and negative, which is formulated entirely in terms of the change in behaviour brought about by particular stimulus manipulations (cf. Michael, 1973; Nevin, 1973). One of the disadvantages of this way of speaking, however, is that the 'explanation' is always retrospective. Many critics of behaviourism have pointed to this apparent paradox in definition of reinforcement (cf. Chomsky, 1959), and many experimental analysts of behaviour are examining also the possibilities of interpretations in terms of the discriminative effects of stimuli.

2. Discriminative effects

While reinforcement refers to the antecedent effect of a stimulus, an effect many psychologists do not easily accept (cf. Dews, 1966), the discriminative properties of a stimulus refers to the consequent effects, more consonant with cause and effect notions necessary to any deterministic account of behaviour.

The original definitions of 'discriminative' referred to stimuli "in the presence of which" responding was reinforced (Skinner, 1953), but more recent definitions simply use the term for any function which affects consequent behaviour (Stubbs, 1971). Stubbs' description of the discriminative function of stimuli stresses the fact that, with temporally regular components (for example FI and FR) there is always a fixed relation between the presentation of the brief stimulus and the presentation of food. In these cases, other things being equal, both S^P and S^N have similar 'predictive' power, and both should therefore maintain similar behaviour. (There is still, in this view, room here for a conditioned reinforcing function. See below).

A related view is that which conceptualises the component behaviour as a complex operant (Bigelow, 1971; Neuringer and Chung, 1967), the brief stimulus serving to maintain the integrity of this complex operant. This view, however, emphasises the importance of the component schedules being similar, whereas the discriminative view does not have this restriction - all that is necessary is for the brief stimulus to have a fixed temporal relation to some event, and therefore to have some 'predictive' power.

Stubbs (1971) considers that the discriminative view explains more easily de Lorge's (1971) finding of a difference between S^N and S^P using VI components. With irregular components there should be no discriminative effect, therefore allowing any conditioned reinforcing effect to be paramount. This effect presumably would be much stronger in the case of S^P than S^N. Further experiments utilizing VI and VR components would demonstrate the correctness, or otherwise, of Stubbs' (1971) analysis.

Many theorists have long been concerned with the problem of the 'backward' effect of reinforcers, and some alternative formulations have been suggested. Hendry (1969), in his concluding comments, suggested that the term '<u>maintaining stimulus</u>' be used in those cases where the probability of emission of an operant is effected by its consequences, and the term '<u>controlling</u>

stimulus' be used in those cases where the probability of an operant varies with the presence or absence of a stimulus. Conditioned reinforcers are examples of the former; discriminative stimuli are examples of the latter. He wryly added:

> "I have placed this note on terminology at the end of the book, where some readers may never find it. This will minimise the risk of confusion from defining a term that is never used. If it has any merit, it will presumably survive". (p.402).

Up to the present time, the terms have apparently not survived, but that the idea, at least, has merit is evidenced by the growing concern over this problem of "how do reinforcers work" (cf. Bolles and Moot, 1972, footnote Pp.56-57 and Staddon, 1972 for related reasoning).

Past analyses of second-order schedules have not been framed to provide information of the sort needed to elucidate issues of this kind, but the controversy between conditioned reinforcing, and discriminative stimulus, explanations show that the problem has not gone unnoticed.

INTRODUCTION TO THE EXPERIMENTS

INTRODUCTION TO THE EXPERIMENTS

The experimental work is presented in three sections. In Section I, two experiments are presented which investigate the nature of the schedule control of (drl) operants, by manipulating the overall schedule contingencies. In the experiments described in Section II, response requirements were manipulated, and the effects of such manipulations on response patterning were analysed. In Section III, a series of experiments is described concerned with the effects of brief stimulus changes on the response patterning maintained by second-order schedules.

Apparatus

Three identical experimental chambers were used. For all of the rats except E-1 and E-2, the same chamber was used throughout the experiment. In the case of E-1 and E-2, the fixed-ratio manipulations were made in one chamber (see Chapter 6), while the brief stimulus changes were made in the same chamber as for E-3 and E-4 (see Chapter 9).

Each operant conditioning chamber measured 18.5 cm from grid to ceiling, 24.0 cm from the back to the front panel, and was 20.0 cm wide. The sides were of sanded, plate aluminium. On the front panel was mounted a lever, 5.0 cm wide, 1.0 cm thick, protruding 2.0 cm from the panel. A force of 0.1 N was needed to depress the lever, and thus to make an electrical contact and record a response. A new response could not be recorded until the lever had returned to rest. The centre of this lever was 2.5 cm from the left hand wall.

A recess, 4.0 cm wide, 5.0 cm high, and 5.0 cm deep was located centrally in the panel, its base being 1.0 cm from the grid. The reinforcer was a solution containing 33.3% Nestle's full cream milk in 66.7% water. The solution was delivered in 0.05 ml portions to the floor of the recess by a motor-operated dipper mechanism, the rest position being up. The dipper cup was located 2.0 cm from the front of the recess.

Each chamber was housed in a sound-attenuating box, lined with polystyrene, and with an extractor fan mounted on the side of the larger chamber providing an ambient noise level of 60 ± 2 db. No illumination was present at any time during any of the experiments. These chambers were housed in a room used solely for this purpose, in which there was very little activity, and no noise permitted. Programming and recording equipment were housed in a separate room.

Solid-state logic units were used to programme the experiments. Responses, reinforcements and completed components were recorded on electromechanical counters. Responses and reinforcements were also recorded on a cumulative recorder, generally Gerbrand's, but occasionally one made in our laboratory. Interresponse times were recorded on Sodeco print-out counters, or, as in the early stages of the experiment reported in Chapter 7, on a Kienzle print-out counter. All brief stimuli were of 100 Hz frequency, obtained by feeding the output from a frequency generator through an amplifier to the speaker.

The random-ratio schedules were programmed by pre-punched tapes, made up using random number tables. Each input resulted in one step of the tape, and an output resulted when a punched hole passed a light sensor. Reinforcement was then available for the next completed component.

The variable-interval tapes were made up from the calculations of Fleshler and Hoffman (1962), and were therefore constant-probability variable-interval (cf. Catania and Reynolds, 1968). The tape moved continually at a set speed, and a punched hole passing a microswitch halted the tape and gave an output which set-up reinforcement for the next completed component.

Housing arrangements

Animals[•] were housed individually in wire cages, mounted in racks, to enable speedy and efficient daily cleaning. Water was available at all times by means of a tube attached to the door of the cage. For the duration of the experiments, each animal was weighed in the morning, and after taking part in the experiment, was given that amount of food necessary to maintain him at 80% ad libitum body weight. A twelve

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[•] All the animals were obtained from Animal Supplies (London) Ltd.

hour day-night cycle, controlled by an automatic clock, was in effect.

Method of data analysis

All the data presented in this thesis has been calculated from the records taken from the final session under each condition.

The dependent variables were calculated in the following ways. Rates were obtained by dividing the number of instances by the time spent emitting those instances. The time used to calculate running rates was the total session time minus the time spent in postreinforcement pauses.

The interresponse time distributions were calculated in one-second categories for those schedules involving (drl 10-sec) components, and in two-second categories in the case of schedules with (drl 20-sec) components. The conditional probability distributions, where presented, were calculated from the interresponse time distributions using the method given by Anger (1956).

Also calculated from the recorded interresponse times was the duration of each component as a function of its ordinal position from reinforcement, the number of errors in each component, the postreinforcement pauses, and the total amount of time spent in the 'work state' (cf. Schneider, 1969).

Initial training

A method of reinforcing successive approximations to lever-pressing has been used in some of the experiments to be reported in this thesis. This is a commonly used technique, and detailed discussions may be found in most standard laboratory texts.

Criteria of stability

In all cases, a change in the experimental conditions was carried out only when two criteria of response stability were met. These criteria were:

(i) that a minimum period of time - usually twenty hours - had been spent in that condition

(ii) that in any three consecutive days, the overall operant rate should not vary by more than 5% from the mean for those three days.

These two criteria were chosen to take into account the suggestions of Schoenfeld and Cole (1972), who observed that:

> "The system will undergo a transition from its initial level to the steady state resulting from the new set of conditions. The transition may be slow or rapid, simple or complex, but, whatever the case, the notion of stability is embodied in two questions: first, is the transition over? second, how similar are successive measurements at any stage? Such questions would not arise if there were no variation in the measurements, but because physical measures are variable, all ways of dealing with the stability problem are necessarily ways of dealing with variability" (p.141).

SECTION I

MANIPULATION OF THE PARAMETERS OF THE OVERALL SCHEDULE

In this Section, the parameters of the overall schedule have been manipulated in order to determine the effect on the component behaviour, and on the nature of control by the overall schedule. The results of these changes have been compared with the results of similar changes made by other experimenters using comparable schedules involving simple operants.

The importance of this type of comparison between the schedule control of simple and complex operants lies in the assertions of certain theorists (cf. Skinner, 1953; 1972) that the control of complex behaviour may be understood by first analysing the factors which determine simple behaviour patterns. Many critics have argued that there exist differences in kind between the simple and complex behaviours (cf. Chomsky, 1959), and that a detailed analysis of the controlling factors in simple situations will not help us to understand complex ones. Although this arguement has often been countered on 'logical' grounds (cf. McCorquodale, 1970), there have been few direct empirical tests of the hypothesis that complex behaviour may be controlled in the same way as simple behaviour.

The two experiments presented in this Section form part of an attempt to test this hypothesis.

CHAPTER 3

Fixed-ratio control of spaced responding

There are several published reports of the maintenance of complex operants under FR schedules (cf. Bigelow, 1971; Boren, 1973; Davidson and Osborne, 1974; Ferster, 1958; 1960; Mintz, Mourer, and Weinberg, 1966; Nevin, Cumming, and Berryman, 1963). The present experiment is an attempt to extend the generality, if any, of the findings of these studies to the FR control of DRL behaviour.

METHOD

Subjects

Four naive male albino rats were maintained at approximately 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage. At the start of the experiment, all the animals were 130 ± 10 days old.

Apparatus

The standard experimental chamber was used.

Procedure

Lever press responses were shaped, followed by continuous reinforcement for 50 responses. Two of the subjects (E-1 and E-2) were then placed on DRL 10-sec (nominally FR 1(drl 10-sec)), and the other 2 subjects (E-3 and E-4) under DRL 20-sec (nominally FR 1(drl 20-sec)). FR values of 1, 2, 4 and 6 were used, the animals being exposed to each value in ascending order. Behaviour stability was obtained under each FR value before proceeding to the next value (see p. 48), the proviso having been made that each subject should have been exposed to each FR value for at least 20 sessions. Table 3:1 gives the number of hourly sessions in each condition for each subject.

TABLE 3:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
E-1	FR1(drl 10-sec)	53
	FR2(drl 10-sec)	20
	FR4(drl 10-sec)	21
	FR6(drl 10-sec)	92
E-2	FR1(drl 10-sec)	49
	FR2(drl 10-sec)	14
	FR4(drl 10-sec)	22
	FR6(drl 10-sec)	97
E-3	FR1(drl 20-sec)	54
	FR2(drl 20-sec)	18
	FR4(drl 20-sec)	25
	FR6(drl 20-sec)	43
E-4	FR1(drl 20-sec)	68
	FR2(drl 20-sec)	23
	FR4(drl 20-sec)	33
	FR6(drl 20-sec)	29

RESULTS

Figure 3:1 shows the median and interquartile range of the duration of the postreinforcement pause. Three of the subjects showed an increase in the pause, together with an increase in variance, as the FR was increased. In the case of E-3, however, there was a longer pause under FR 2(drl 20-sec) than under FR 4(drl 20-sec). Apart from this exception, however, there was a trend of increasing postreinforcement pause with increasing FR value.

The relative frequency distributions of IRTs are shown in Fig. 3:2. Both of the rats with (drl 20-sec) components showed a shift in the distribution to the right, i.e. a tendency to emit longer IRTs as the FR value was increased. The effect was not evident, however, for the 2 rats with (drl 10-sec) components except on transition from FR 1 to FR 2.

The overall response rate under each condition is shown in Fig. 3:3. In the case of 3 of the rats, response rate decreased as the FR value was increased, while the

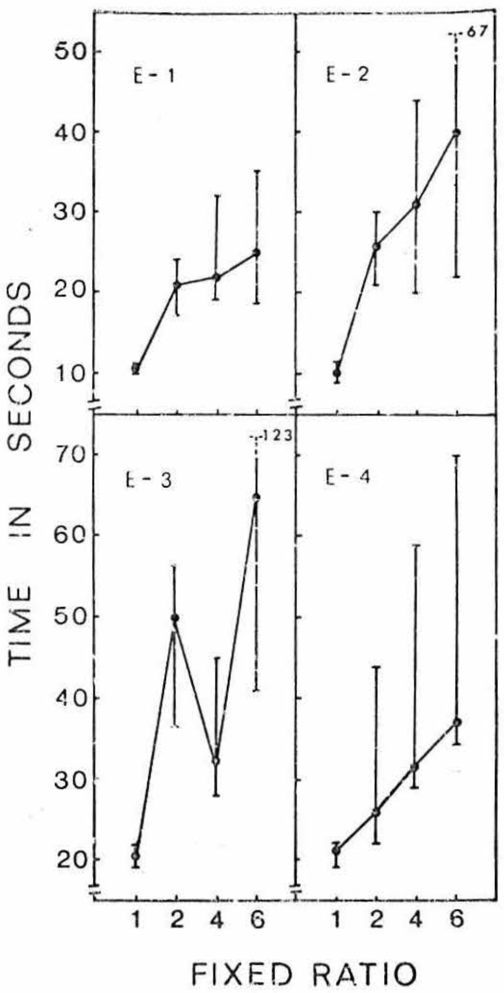


Figure 3:1

The median value, and interquartile range, of the duration of the postreinforcement pause under each condition.

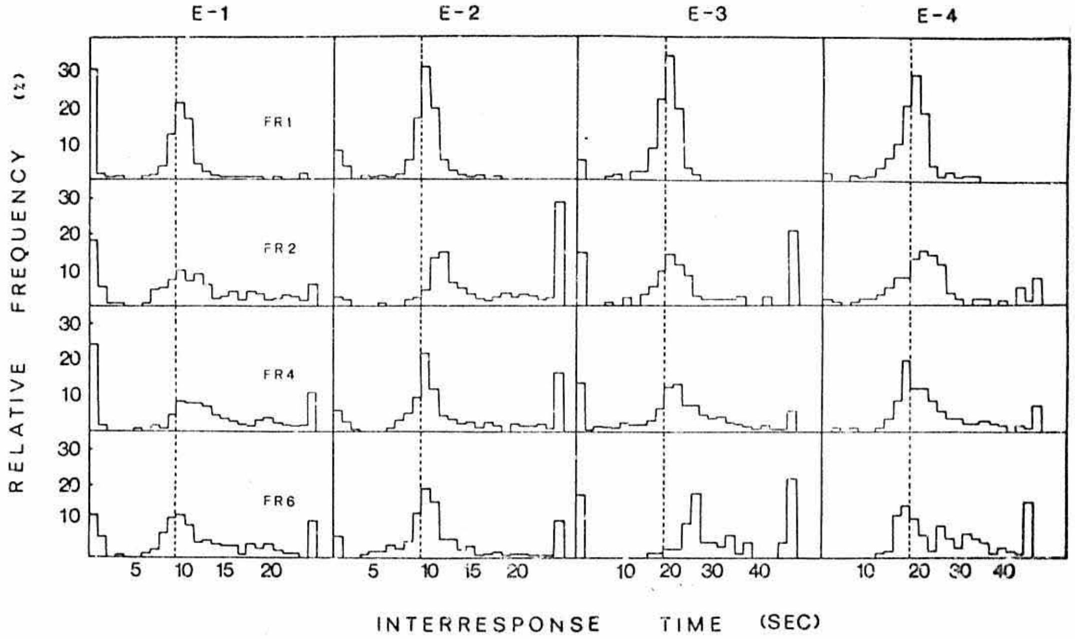


Figure 3:2

The relative frequency distribution of the interresponse times under each value of the ratio. For the rats with (drl 10-sec) components, 1 sec categories are used. For the rats with (drl 20-sec) components, 2 sec categories are used. The last category contains all IRTs of that value and greater.

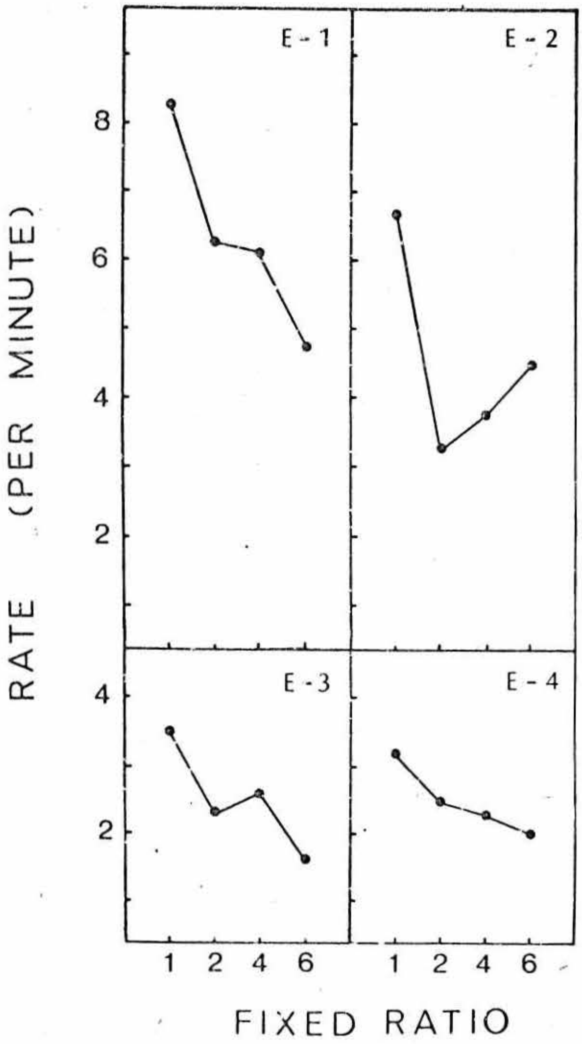


Figure 3:3

The overall rate of lever pressing under each condition.

response rate of E-2 increased on changing from FR 2 up to FR 6. For all of the rats, however, the number per unit of time of IRTs which met the DRL criterion (the component rate) decreased as a function of the FR value. This is shown in Fig. 3:4, along with the running rate of components, or 'correct responses'. The decrease in this variable as a function of increasing the ratio was particularly marked.

Figure 3:5 shows the mean value of successive (drl) components within the ratio. This was calculated by taking an average of the IRTs which satisfied each of the (drl) components within the interval. The first component happened to be the postreinforcement pause, while the last component was always followed by reinforcement. Component duration was found to be a decreasing function of relative 'distance' from the preceding reinforcement. The IRTs which satisifed the DRL criterion got shorter (nearer to the criterion value) as reinforcement approached. There was also an increase in the duration of each component as the FR was increased. For example, the third component was always longer under FR 6(drl) than under FR 4(drl). The interquartile ranges of the durations of each component are shown for FR 6(drl) in Fig. 3:6. The

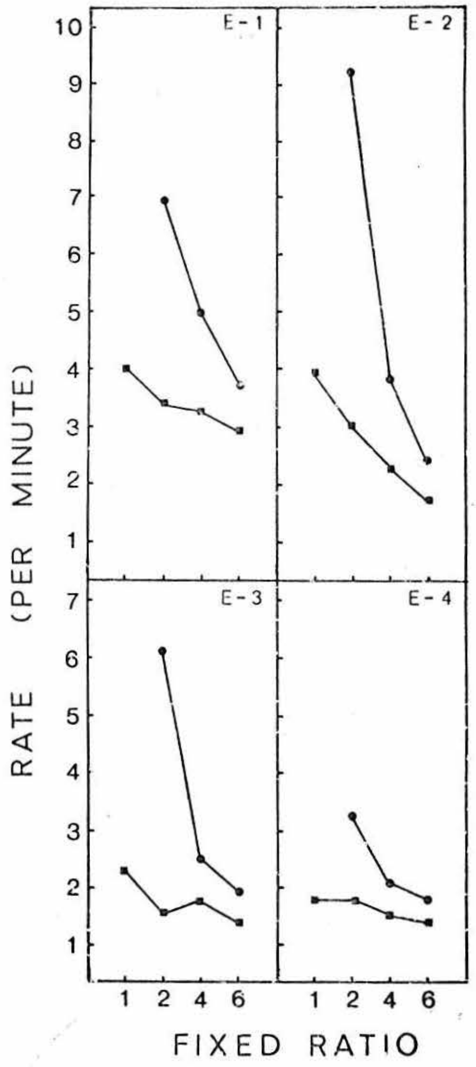


Figure 3:4

The overall rate of emission (squares) and running rate (circles) of (drl) components.

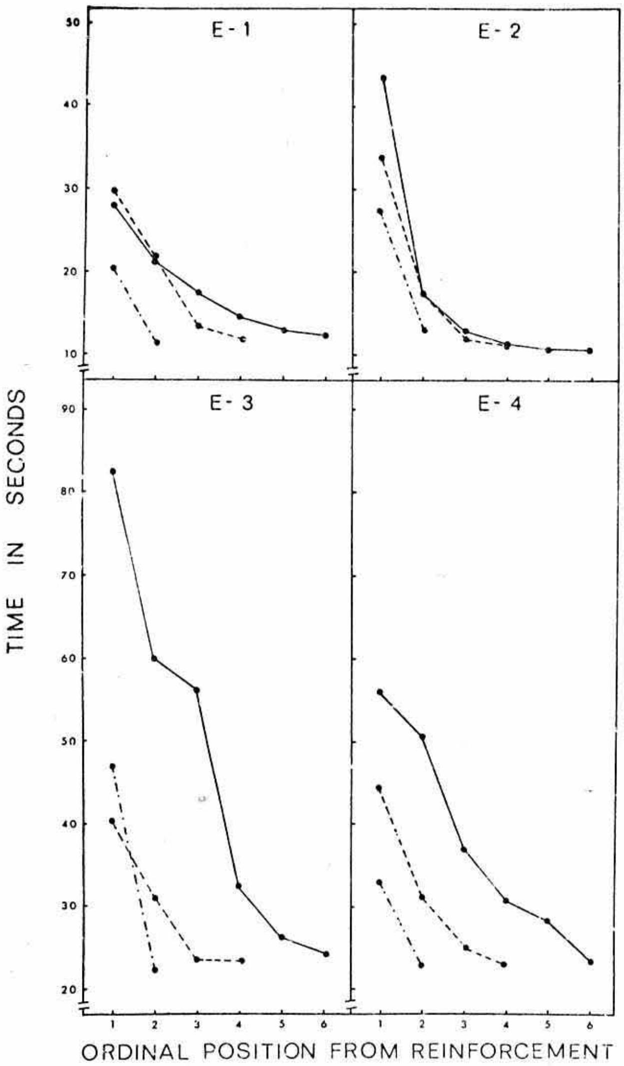


Figure 3:5

The mean duration of each IRT satisfying each (drl) component within the interreinforcement interval. The solid line is the FR6(drl) function; the dashed line is the FR4(drl) function; the dots-and-dashes represent the FR2(drl) function.

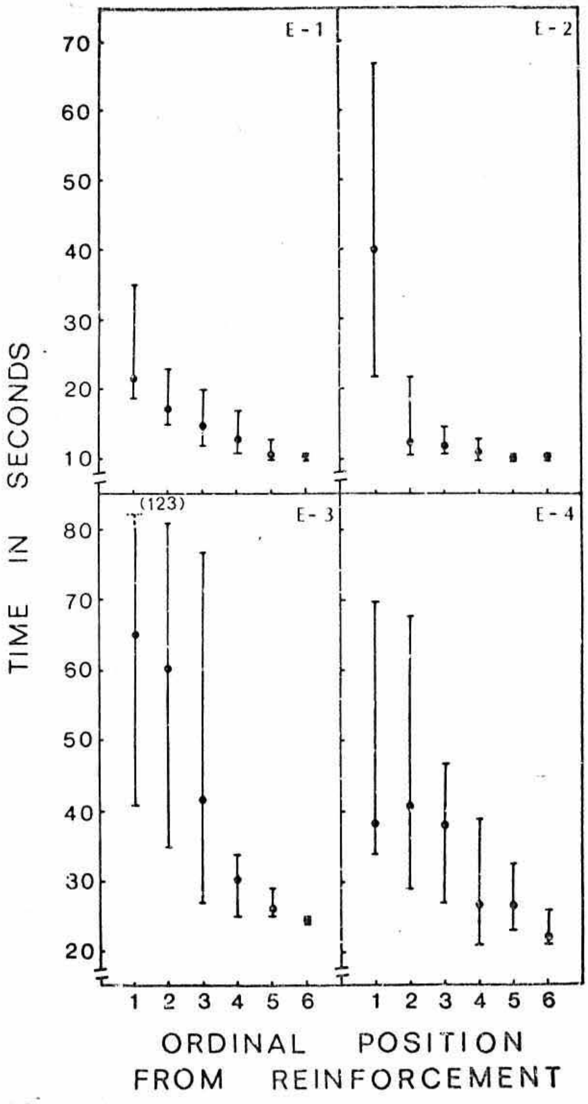


Figure 3:6

The interquartile range of the IRTs satisfying each (drl), for FR6(drl) only.

effect was the same for the other FR value, but in the interests of clarity they are not shown. The obtained effect was of decreasing variability as reinforcement was approached. There was a wide range of IRTs emitted to satisfy the first component, but all of the IRTs which satisifed the final component were very near to the required value.

Table 3:2 and Fig. 3:7 show the 'errors' made in each component, both as a function of FR value, and as a function of ordinal position from reinforcement. There was an increase in the frequency of IRTs not satisfying the DRL criteria as reinforcement approached, and a decrease in the frequency of 'errors' in most cases in any particular component as the ratio was increased. There was also a decrease in the total number of 'errors' as the FR value was increased. These effects were most marked under the FR 2 and FR 4 conditions. In the case of E-3, where there was a downward trend in the FR 6 function, very few 'errors' were made at all in any component.

Sample cumulative records are shown in Fig. 3:8. One set is from a rat with (drl 10-sec) components, the other set from a rat under (drl 20-sec) components. The formation of a 'scallop' may be clearly seen, being shallower under (drl 20-sec).

TABLE 3:2

Mean Number of Errors Made in Each Component

		ORDINAL POSITION OF THE COMPONENT FROM REINFORCEMENT					
SUBJECT	SCHEDULE	1	2	3	4	5	6
E-1	FR2(drl 10-sec)	0.14	1.20				
	FR4(drl 10-sec)	-	0.30	0.75	1.00		
	FR6(drl 10-sec)	0.03	-	0.17	0.17	1.76	1.52
E-2	FR2(drl 10-sec)	-	0.18				
	FR4(drl 10-sec)	0.02	0.20	0.55	0.75		
	FR6(drl 10-sec)	-	0.75	0.63	0.25	0.37	0.79
E-3	FR2(drl 20-sec)	0.15	0.55				
	FR4(drl 20-sec)	-	0.63	0.41	0.59		
	FR6(drl 20-sec)	-	0.46	0.23	0.08	0.15	-
E-4	FR2(drl 20-sec)	0.25	0.52				
	FR4(drl 20-sec)	0.09	0.50	0.73	0.86		
	FR6(drl 20-sec)	-	0.21	0.28	0.71	0.93	0.93

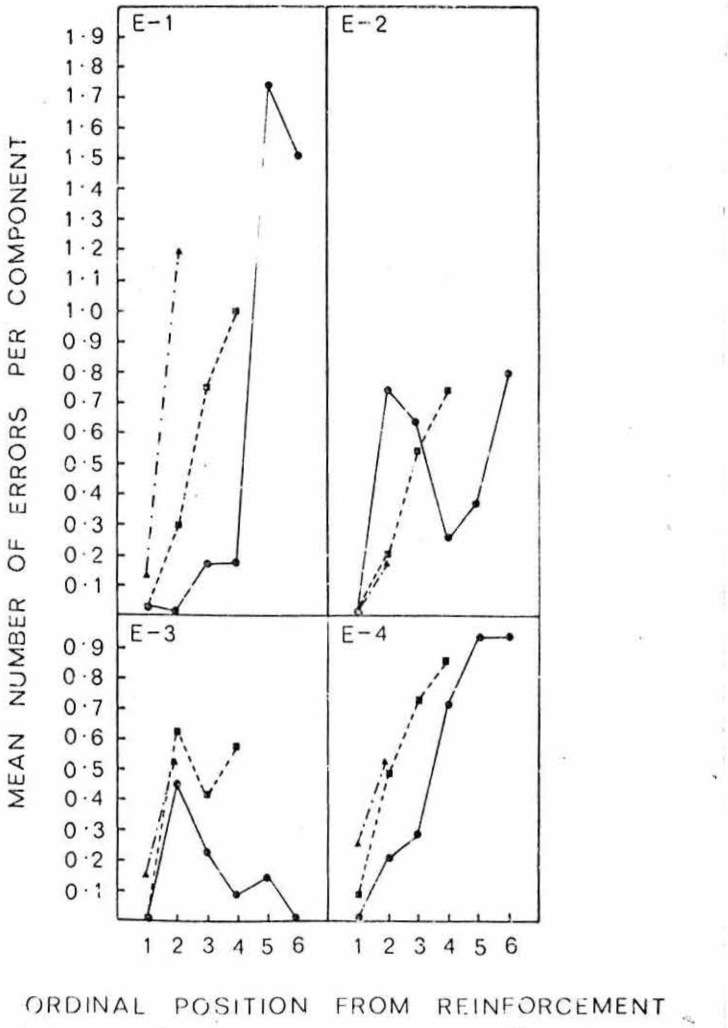


Figure 3:7

The mean number of errors, or IRTs not satisfying the (drl) requirement, per component. The triangles represent the FR2(drl) condition; the squares represent the FR4(drl) condition; the circles represent the FR6(drl) condition.

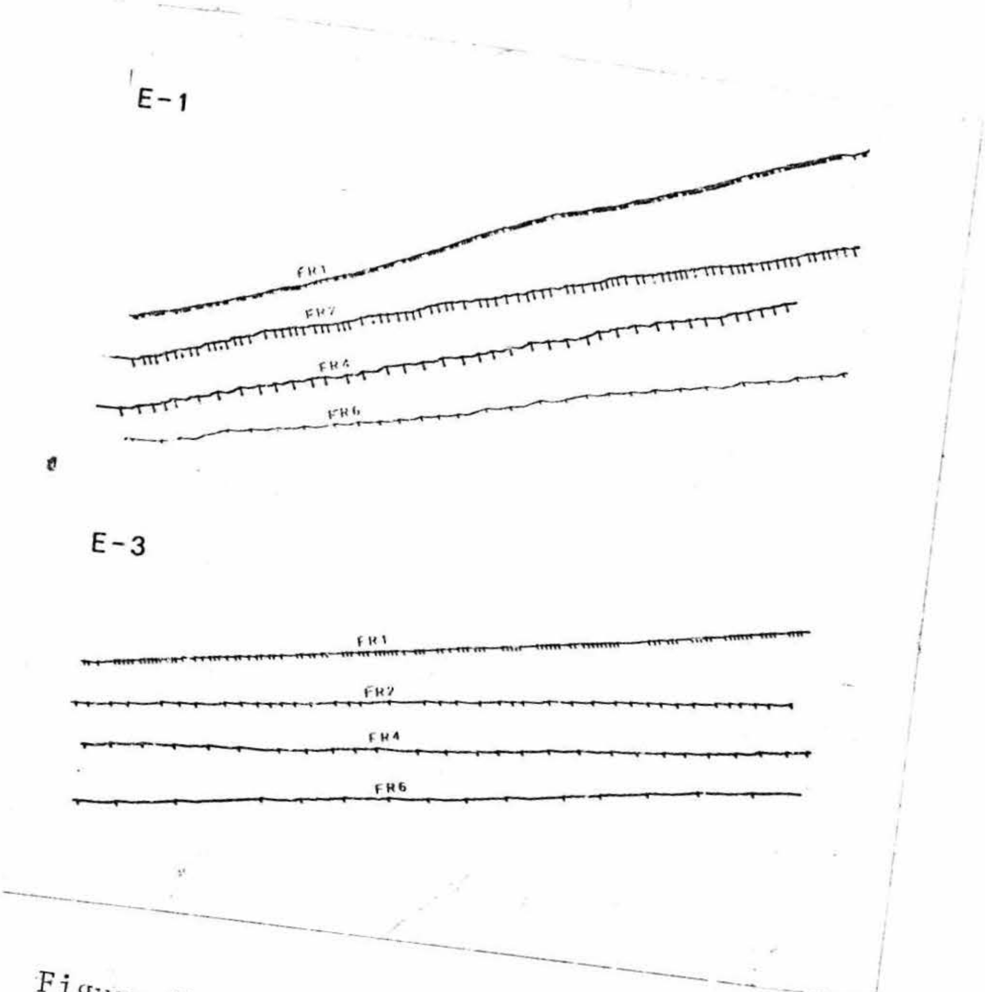


Figure 3:8

Cumulative records taken during the final session under each ratio value.

DISCUSSION

Typically, under FR schedules, reinforcement is followed by a pause, which leads to a steady rate of responding until the next reinforcement (cf. Ferster and Skinner, 1957). The effect on this behaviour of manipulating the ratio are, however, less clear.

It has been consistently reported that post-reinforcement pause duration is an increasing function of ratio size (cf. Felton and Lyon, 1966; Ferster and Skinner, 1957; Powell, 1968; 1969), but a change in running rate has seldom been reported. In most studies, this measure has not been used, although it has been shown to be especially sensitive to experimental manipulations under FI schedules (cf. Elsmore, 1971; Schneider, 1969). As FR and FI are often considered to be similar in many respects (cf. Nevin, 1973; Schoenfeld and Cole, 1972), it seems likely than an analysis in terms of running rate on FR schedules might prove useful.

Felton and Lyon (1966) and Powell (1968; 1969) suggested that running rate may have been a decreasing function of ratio size for some of their animals, but concluded that there was no real systematic relationship.

Jwaideh (1973) suggested that running rate is insensitive to changes in ratio size, while Epling and Lloyd (1973), using a conjunctive FR FI, showed a decrease in running rate with increasing ratio size for all of their pigeons.

With regard to the overall rate of responding, some studies have shown it to be an increasing function of ratio value (cf. Boren, 1961; Premack, Schaeffer, and Hunt, 1964; Weissman and Crossman, 1966), or that it increases to a maximum, then decreases (cf. Barofsky and Hurwitz, 1968; Lee and Gollub, 1971).

The rats used in the present experiment showed an increase in postreinforcement pause with increasing ratio size (Fig. 3:1). Powell (1968) reported also an increase in the variability of postreinforcement pause duration with increasing ratio, a finding replicated by this experiment.

The overall rate of lever pressing decreased with increasing ratio value for 3 animals, but increased on changing from FR 2 to FR 6 for E-2 (Fig. 3:3). The relevance of overall response rate measures for studies of complex operants has been questioned by other authors (cf. Bigelow, 1971; Stubbs, 1971), and the results of the present study also case doubt on the usefulness of this particular dependent variable.

The rate of emission of components, however, was comparable to the rate of lever pressing observed under simple FR schedules. Both the overall and running rate of components was a decreasing function of ratio value (Fig. 3:4). Both Barofsky and Hurwitz (1968) and Lee and Gollub (1971) reported decreasing response rate with increasing ratio value. They obtained this effect with high FR values, and a factor which might connect these two studies with the present experiment is the relatively long interreinforcement times involved. It is well documented that decreasing reinforcement frequency decreases rate of responding (cf. Hernstein, 1970). This, however, is a molar explanation and the emphasis in the present thesis is on molecular analysis. This point is discussed at greater length later.

Furthermore, the account in terms of reinforcement frequency does not apply to the results of Bigelow (1971). He reinforced an operant of (drl 4.5-sec) under FR values of 20, 8, and 3, and found an <u>increase</u> in the overall component rate with increasing ratio value. There are certain procedural differences between the Bigelow (1971) study and the present experiment. In addition to presenting an S^P after each component, Bigelow used a very short (drl) value. The present study involved a tandem schedule, and used much longer (drl) values. (Many experimenters have reported considerable rate differences between tandem and S^P conditions (cf. Stubbs, 1971), but whether or not this is an absolute effect, acting between different experiments, is quite unclear). Whereas Bigelow (1971) decreased his ratio values, those in the present study were increased.

Three of Bigelow's 4 rats, however, decreased their component running rates as the FR value increased, which is the same effect as reported here. Epling and Lloyd (1973) also reported a decrease in running rate with increasing ratio value under a conjunctive FR FI. These three experiments are the only ones to report this effect.

Several authors have suggested that schedules of time-consuming operants may reveal aspects of schedule control not apparent with more instantaneous operants (cf. Bigelow, 1969; 1971; de Lorge, 1969; Marr, 1969). If this were true, then this discrepancy might be explained. Felton and Lyon (1966) and Powell (1968) reported occasional decreases in running rate for some animals with a simple operant. Bigelow (1971) reported a decreasing function for 3 of his 4 rats with a (drl 4.5-sec) operant. The present study showed a substantial decreasing effect for all animals with operants of (drl 10-sec) and (drl 20-sec). This hypothesis will be discussed at the end of Section I, but there is another aspect of the situation which might elucidate the finding of a decreasing running rate.

Figure 3:8 shows the formation of a clear scallop as the FR values increases. Bigelow (1971) also observed this effect when a cumulative recording was obtained in which the pen was stepped only by 'correct' responses. This scallop is similar to that obtained under FI schedules of reinforcement (cf. Ferster and Skinner, 1957). Response rate is known to decrease with increasing interreinforcement interval under FI schedules (cf. Nevin, 1973; Skinner, 1938). It may be the case, therefore, that behaviour under FR (drl) is controlled by similar variables to those controlling FI behaviour. Some authors have cast doubt on the traditional separation of FI and FR schedules (cf. Nevin, 1973; Schoenfeld and Cole, 1972), and the work of Schoenfeld and his collaborators has shown that there is an easily obtained transition between ratio and interval type behaviour (cf. Hearst, 1958).

Usually, the characteristics of the component are maintained under second-order schedules, at least in the S^P condition. The present experiment shows that the characteristics of responding with reference to the component schedule were affected to some extent by the overall schedule. For example, none of the animals was as precise in temporal discrimination at higher ratios as at FR 1(drl). Also, for both of the subjects under (drl 20-sec), there was a clear tendency to emit longer IRTs as the ratio was increased.

Figures 3:5 and 3:6 provide a more detailed account of the performance in each component, and it can be seen that component behaviour changed systematically both between and within ratios. The main effect was of a decrease in the mean IRT to satisfy the component criterion as reinforcement on the overall schedule approached. These functions are very similar in form to those obtained by Davison (1969). He examined successive IRTs in simple FR and second-order FR(FR), and found that the duration of IRTs decreased as reinforcement approached.

Related to the decreasing component duration was the finding that more errors occurred in the latter half of the ratio than in the first half (Fig. 3:7, Table 3:2). Bigelow (1971) reported that his subjects made more errors in the first half of the ratio. Other studies using complex operants under FR control also report more errors in the first half of the ratio than in the second half (cf. Davidson and Osborne, 1974; Mintz et al. 1966; Nevin, 1967; Nevin et al. 1963).

Two possibilities may be considered with regard to the error findings. Although Bigelow has stated that there is:

> "...a clear tendency for errors to occur during the earlier part of the fixed-ratio" (1971, p.27).

an analysis of his data by the present writer has shown that these differences were not statistically significant.

Secondly, it may be considered that 'errors' in other complex operants are controlled by totally different variables than those controlling 'errors' in the present study, and that of Bigelow (1971).

There are very few reports of behaviour under DRL control without 'errors' (cf. Kramer and Rilling, 1970) and it has often been suggested that these non-criterion IRTs play an important role in DRL behaviour, in that they "set the occasion for longer, criterion IRTs" (cf. Angle, 1970; Ferraro, Schoenfeld, and Snapper, 1965; Kramer and Rilling, 1970). On the other hand, 'mistakes' made in other complex operant studies, such as matching-to-sample, play no important part in the maintenance of the behaviour. There are many studies where these tasks have been taught without errors (cf. Lambert, 1974; Terrace, 1966). It appears to be the case, then, that 'errors' in a DRL situation are an <u>integral</u> part of the behaviour whereas 'errors' in other situations may be merely <u>incidental</u> to the behaviour.

The reinforcing stimulus has two functions. One is to <u>maintain</u> the behaviour upon which it is contingent, and the other is to control the behaviour which follows it (cf. Hendry, 1969; Reid, 1958; Staddon, 1972). In the present experiments, the maintained behaviour would be typical DRL behaviour (with 'errors), and the controlled behaviour would take the form of long pauses, as on most schedules with long inter-reinforcement times. In the present experiment, then, there should be few 'errors' in the first half of the ratio and more in the second half. This was exactly the case. (cf. also Thomas and Stubbs, 1966).

When a matching-to-sample task is reinforced according to a FR schedule, the maintained behaviour should be matching-to-sample with few 'errors' (since they are incidental to the behaviour), and this has been shown to be true. The controlled behaviour would not be specified by the schedule contingencies, and so could take the form of responding inappropriately, and therefore making 'errors'. This also is the case. It seems likely that any behaviour other than matching-to-sample would constitute an 'error' in this situation and it is well documented that reinforcement causes an immediate decrease in the frequency of the behavior it usually maintains (cf. Catania, 1973 c), thus allowing the opportunity for 'errors' to occur in this type of matching-to-sample situation.

This explanation is ex post facto but has the advantage of appealing only to generally acknowledged controlling variables. The hypothesis is, that as reinforcement is approached on a temporally regular schedule, the component behaviour becomes more similar to that normally obtained under the component schedule, and this transition is due to a transition from the controlling to the maintaining function of the reinforcing stimulus. This hypothesis, however, would need rigorous empirical validation before it could be accepted as a principle of the control of behaviour.

There are several aspects of the present experiment which suggest that FR schedules exert similar control over both simple and complex operants. The comparison, however, is made very difficult by lack of a detailed understanding of the FR control of simple operants, a deficit which the experimental analysis of behaviour should rectify as soon as possible.

CHAPTER 4

Random-ratio control of spaced responding

A random-ratio (RR) schedule is one which specifies that each response has an equal probability of being followed by reinforcement (Brandauer, 1958). For example, a RR 8 schedule specifies that each response has the probability of 0.125 of being reinforced. The present experiment was an investigation into the effect on behaviour maintained by two DRL schedules of manipulating the parameters of an overall RR schedule.

METHOD

Subjects

Three naive, male hooded rats, and one naive, male, albino rat served. Each was maintained at approximately 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage. At the start of the experiment, two of the subjects (B-1 and B-2) were 120 ± 10 days old, while the other two (C-3 and E-5) were 200 ± 20 days old.

Apparatus

The standard experimental chamber was used.

Procedure

After lever training, each animal was given 50 reinforcements on a continuous reinforcement schedule. Subjects B-1 and B-2 were then reinforced under DRL 10-sec (nominally RR 1(drl 10-sec)), and subjects C-3 and E-5 under DRL 20-sec (nominally RR 1 (drl 20-sec)).

After the rats had been on each condition for a minimum of 20 hourly sessions, and having satisfied the stability criteria mentioned above (p.48), then the RR values were changed. For 3 of the 4 rats, the requirement was raised from RR 1 to RR 2 to RR 4 to RR 8. For subject C-3, the requirement was changed directly to RR 4 from RR 1. The reason for this was that C-3 was a late replacement for an animal that died, and consequently there was less time available in which to complete the experiment.

Table 4:1 gives the number of sessions under each condition for each subject.

RESULTS

Figure 4:1 shows that the duration of the postreinforcement pause increased with RR value for each subject. For both of the animals on RR 1 (drl 10-sec), these data were not available, although it may be taken that the pause was about 10 sec in duration in both cases, due to the length of time under this condition.

The relative frequency distribution of IRTs is shown in Fig. 4:2, and a tendency to emit longer IRTs as the RR value was increased is evident for all of the subjects.

Figure 4:3 shows that there was no systematic effect on the overall rate of lever pressing of changing the ratio requirements. The overall component rate was insensitive to the changes in ratio requirement,

TABLE 4:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
B-1	RR1(drl 10-sec)	33
	RR2(drl 10-sec)	25
	RR4(drl 10-sec)	63
	RR8(drl 10-sec)	50
B-2	RR1(drl 10-sec)	36
	RR2(drl 10-sec)	25
	RR4(drl 10-sec)	62
	RR8(drl 10-sec)	52
C-3	RR1(drl 20-sec)	102
	RR4(drl 20-sec)	39
	RR8(drl 20-sec)	34
E-5	RR1(drl 20-sec)	75
	RR2(drl 20-sec)	25
	RR4(drl 20-sec)	25
	RR8(drl 20-sec)	40

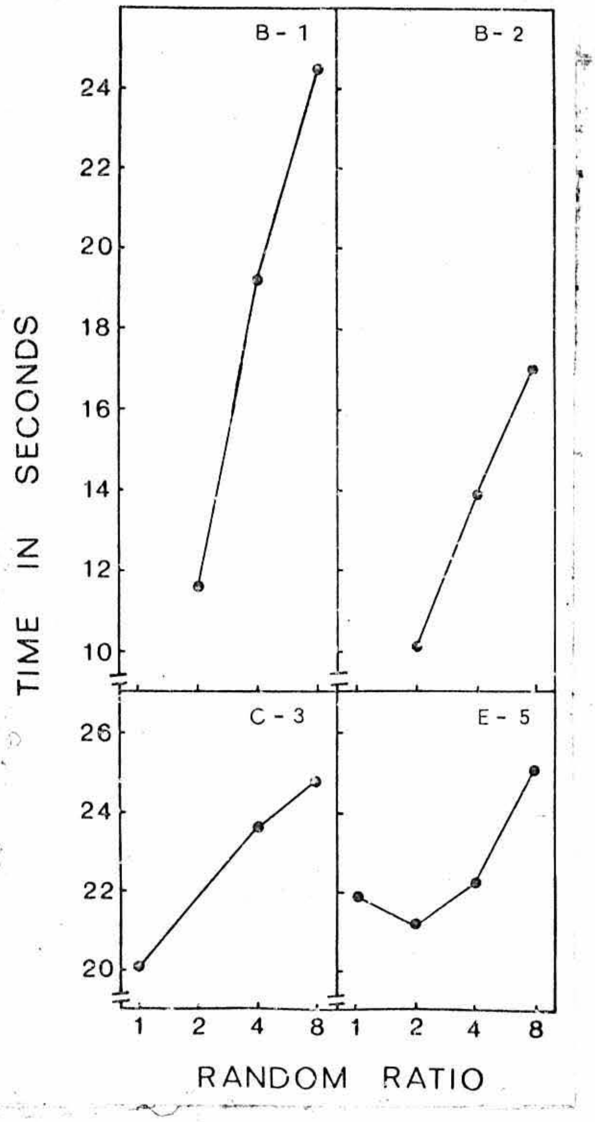


Figure 4:1

The mean value of the duration of the postreinforcement pause under each condition.

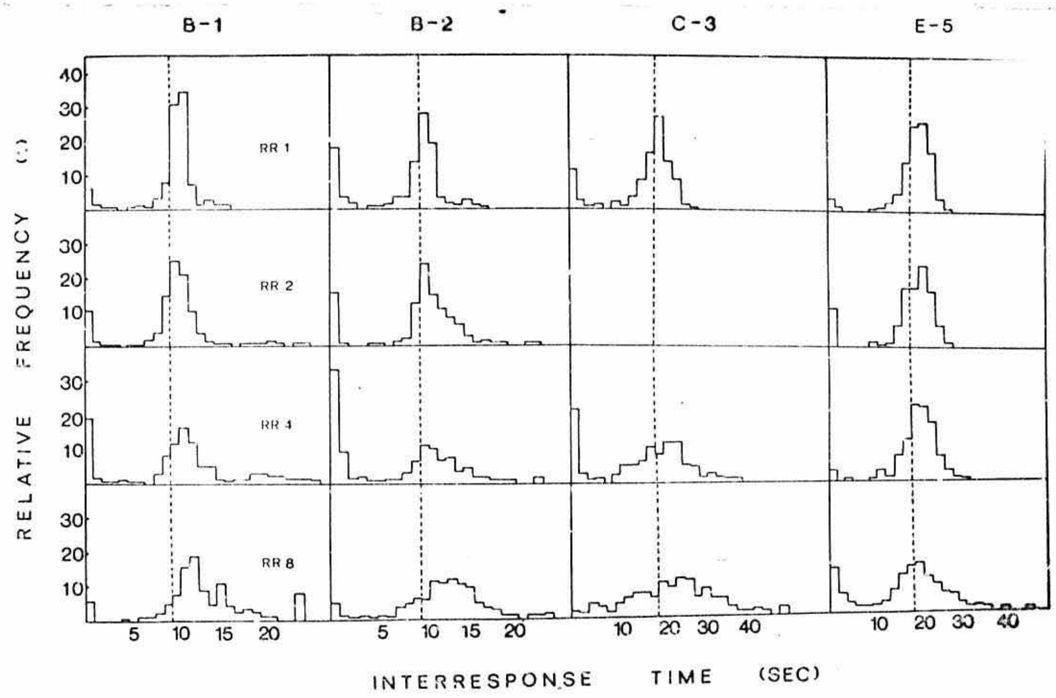


Figure 4:2

The relative frequency distribution of the interresponse times under each value of the ratio. For the rats with (drl 10-sec) components, 1 sec categories are used. For the rats with (drl 20-sec) components, 2 sec categories are used. The last category contains all IRTs of that value and greater.

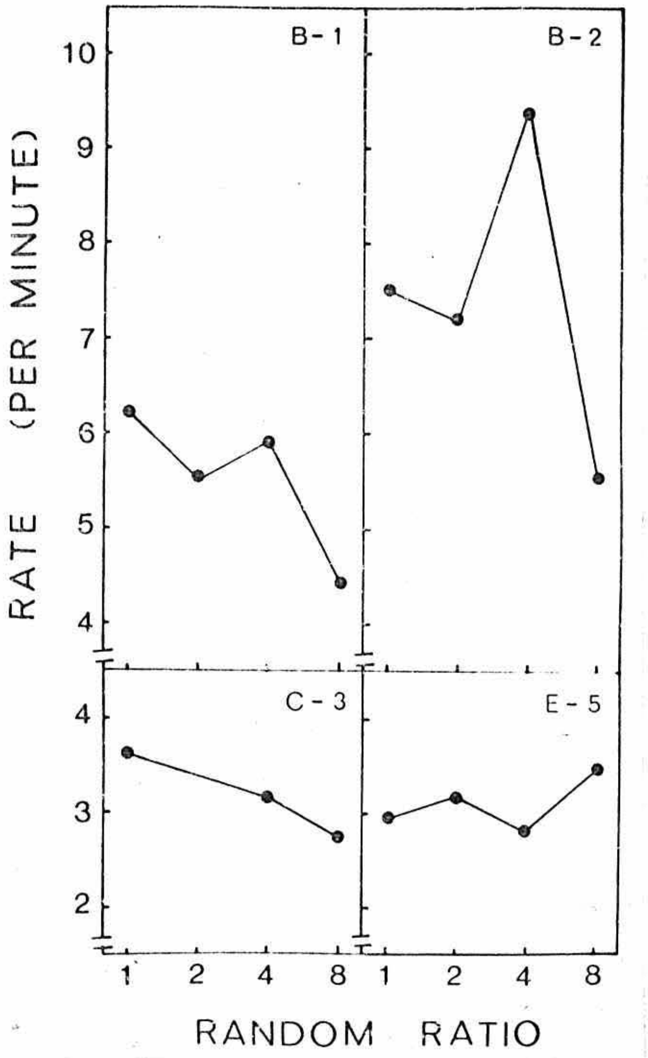


Figure 4:3

The overall rate of lever pressing under each condition.

while the component running rate decreased as the RR requirement increased (Fig. 4:4). An exception to this, however, was B-2, whose running rate increased on changing from RR 4 to RR 8. This is also the animal who showed most variability in the other rate measures.

The mean duration of the IRTs satisfying each component as a function of RR value and ordinal position from reinforcement is shown in Fig. 4:5. For both of the rats with (drl 10-sec) components, after the first two, the duration of the remaining components remained constant to reinforcement. For the (drl 20-sec) rats, there was no appreciable difference in duration of the components at each RR value, although the functions are more variable than for the (drl 10-sec) rats. In the case of 3 of the subjects, the RR 8 function was higher than the RR 4 function, which in turn was higher than the RR2 function. In the case of B-2, the RR8 function was below the RR4 function for 4 components.

Tables 4:2 and 4:3, and Fig. 4:6 show the 'errors' made in each component as a function of RR value, and ordinal position from reinforcement. Because of the inequality in the number of instances of each ordinal component, the ordinate of Fig. 4:6 represents the number

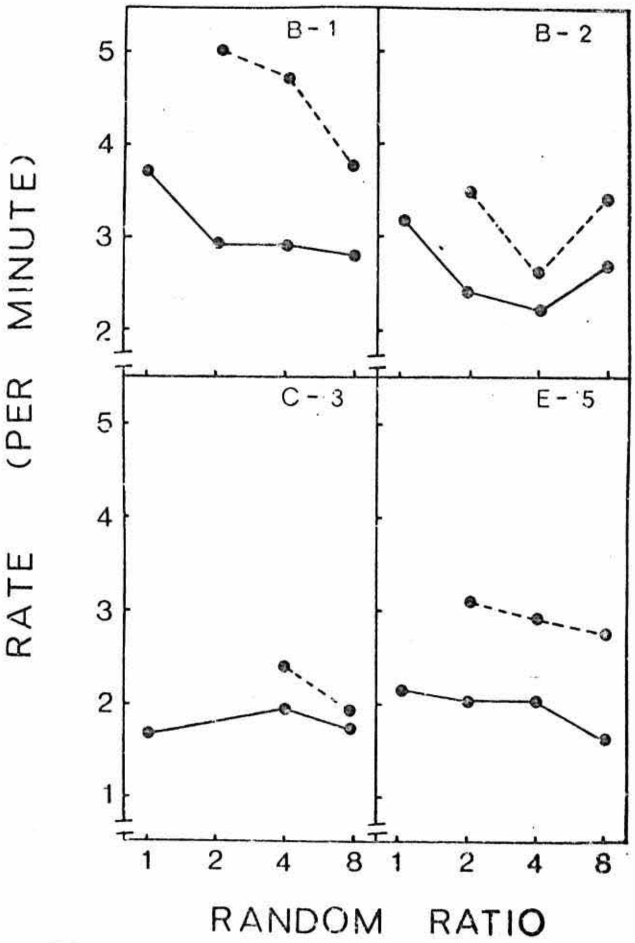


Figure 4:4

The overall rate of emission (solid line) and running rate (dashed line) of (drl) components.

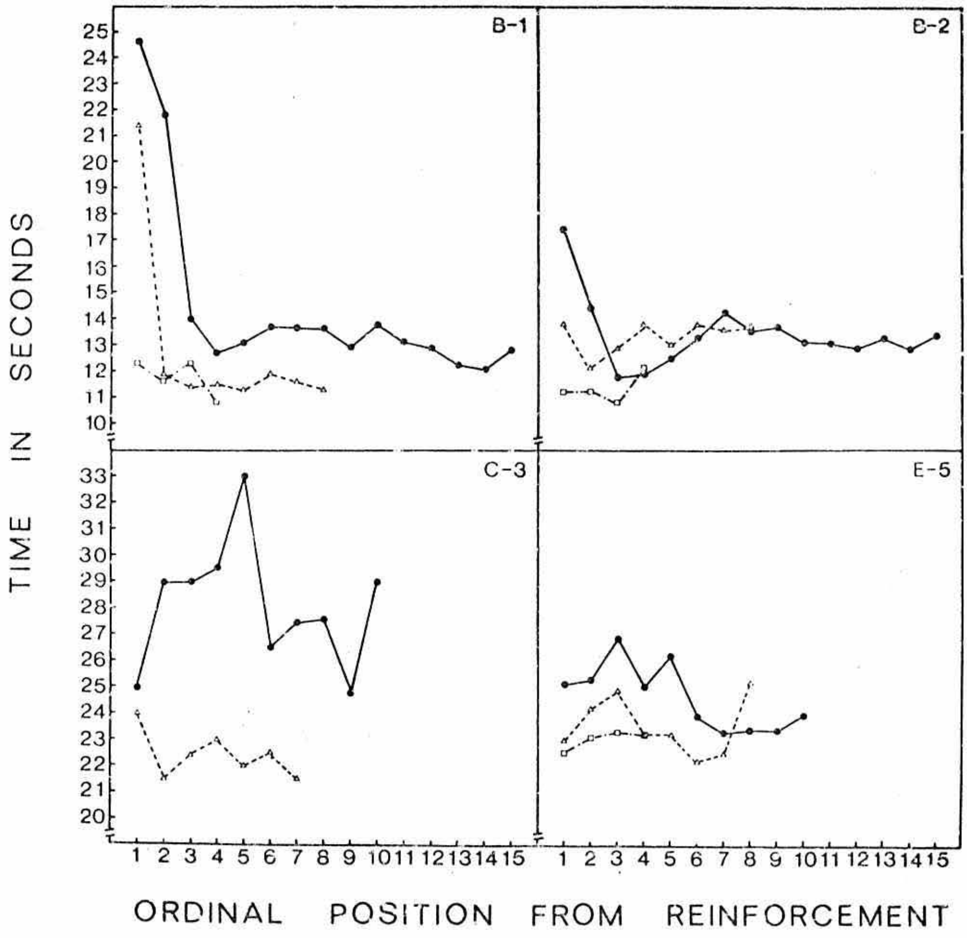


Figure 4:5

The mean duration of each IRT satisfying each (drl) component within the inter-reinforcement interval. The circles represent the RR8(drl) function; the triangles represent the RR4(drl) function; the squares represent the RR2(drl) function.

Table 4:2

Total Number of Errors Made in Each Component

		ORDINAL POSITION OF THE COMPONENT FROM REINFORCEMENT															
SUBJECT	SCHEDULE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
B-1	RR2(drl 10-sec)	47	45	21	9	7											
	RR4(drl 10-sec)	3	24	33	12	15	13	6	3	2	1	-	1	2	1	-	1
	RR8(drl 10-sec)	-	-	7	5	2	1	1	2	3	2	1	2	-	1	1	-
B-2	RR2(drl 10-sec)	59	28	18	8	3											
	RR4(drl 10-sec)	9	58	57	57	33	34	16	12	3							
	RR8(drl 10-sec)	6	12	21	14	2	2	3	1	1	1	1	3	2	3	2	3
C-3	RR4(drl 20-sec)	8	34	16	5	3	7	2	1	1							
	RR8(drl 20-sec)	4	6	2	1	5	4	6	7	1	5	2	-	3	-	-	5
E-5	RR2(drl 20-sec)	33	14	17	16												
	RR4(drl 20-sec)	10	10	4	9	3	4	1	4								
	RR8(drl 20-sec)	18	13	10	13	9	9	7	2	4	3	2	3	4	-	7	4

TABLE 4:3

Mean Number of Errors Made in Each Component

SUBJECT	SCHEDULE	ORDINAL POSITION OF THE COMPONENT FROM REINFORCEMENT															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
B-1	RR2(drl 10-sec)	0.39	0.66	0.57	0.82	1.00											
	RR4(drl 10-sec)	0.05	0.53	0.94	0.48	0.71	0.65	0.46	1.00	1.00	0.50	-	1.00	0.50	1.00	-	1.00
	RR8(drl 10-sec)	-	-	0.30	0.24	0.17	0.09	0.09	0.18	0.30	0.28	0.14	0.28	-	0.14	0.25	-
B-2	RR2(drl 10-sec)	0.47	0.38	0.47	0.67	0.50											
	RR4(drl 10-sec)	0.16	1.14	1.46	1.90	1.65	1.79	1.45	2.00	0.75							
	RR8(drl 10-sec)	0.19	0.44	0.78	0.64	0.12	0.17	0.25	0.08	0.08	0.11	0.11	0.37	0.25	0.37	0.33	1.00
C-3	RR4(drl 20-sec)	0.27	1.36	0.89	0.38	0.30	0.78	0.40	0.33	1.00							
	RR8(drl 20-sec)	0.36	0.67	0.22	0.11	0.62	0.57	0.86	1.00	0.17	1.00	0.50	-	1.00	-	-	1.67
E-5	RR2(drl 20-sec)	0.57	0.40	1.00	1.20												
	RR4(drl 20-sec)	0.30	0.42	0.23	0.75	0.25	0.40	0.17	0.80								
	RR8(drl 20-sec)	1.50	1.30	1.00	1.30	1.12	1.12	1.17	0.40	1.80	1.33	0.67	1.50	2.00	-	3.50	2.00

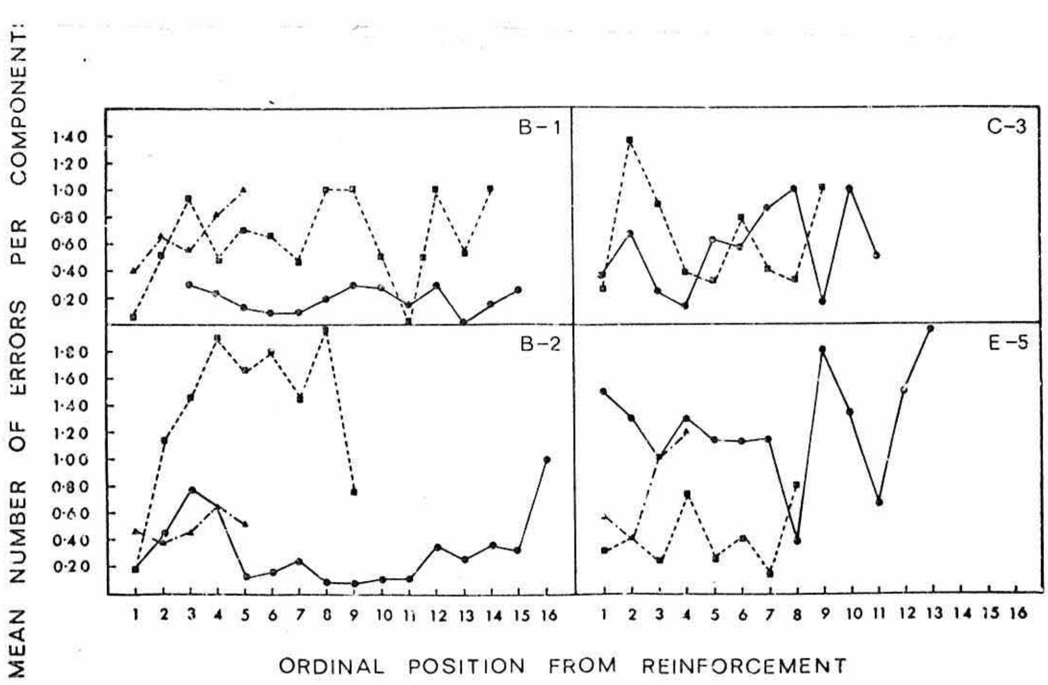


Figure 4:6

The mean number of errors per component. The triangles show the RR2(drl) function; the squares show the RR4(drl) function; the circles show the RR8(drl) function..

of errors made per ordinal component. For each ratio value, the least number of errors was usually made during the first 1 or 2 components, but after this there was no systematic relationship. For both of the animals with (drl 10-sec) components, the function for RR8 was the lowest, but this was not the case for either of the rats with (drl 20-sec) components.

Figure 4:7 shows sample cumulative records from one animal with (drl 10-sec) components, and from one with (drl 20-sec)components . There was no patterning evident, nor any rate differences, between any of the conditions.

DISCUSSION

The finding that the duration of the post-reinforcement pause was an increasing function of RR value extends the generality of the reports of Brandauer (1958), Farmer and Schoenfeld (1967), and Sidley and Schoenfeld (1964). The insensitivity of the overall rate of components to changes in the probability of reinforcement corroborates the findings of Brandauer (1958) and Sidley and Schoenfeld (1964). These two results suggest that the (drl) component

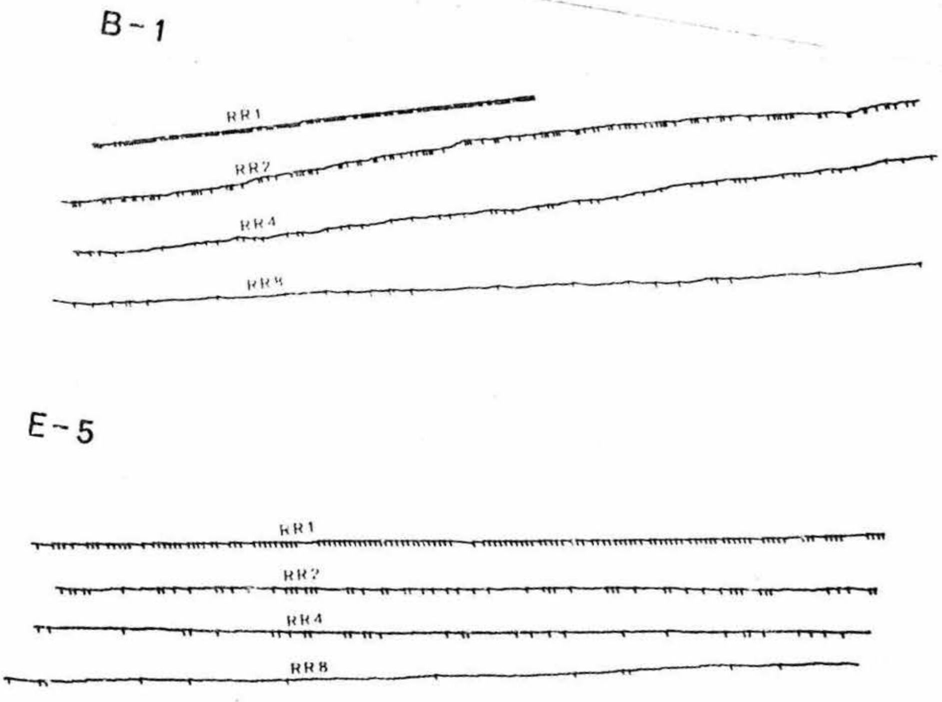


Figure 4:7

Cumulative records taken during the final session under each ratio value.

behaved in much the same way as simple lever-pressing or key-pecking operants. However, the finding that the running rate of components was a decreasing function of RR value is discordant with the report of Farmer and Schoenfled (1967), who said that running rate is insensitive to changes in the probability of reinforcement.

Examination of the IRT distributions (Fig. 4:2) shows that there was a clear tendency to emit longer IRTs as the RR was increased, and this was apparently not caused by any selective effects on particular ordinal components. Indeed, except for the longer postreinforcement pauses in the case of the subjects with (drl 10-sec) components, there was no systematic change in the duration of components as time from reinforcement increased (Fig. 4:5). For the animals with (drl 20-sec) components, there was no increase over the remaining component durations in the post-reinforcement pause. These findings are very similar to those reported by Kintsch (1965) who showed that IRTs on VR schedules show little difference after the postreinforcement pause. This is another point of contact between the schedule control of simple and complex operants.

Brandauer (1958), and Sidley and Schoenfeld (1964) reported that they obtained the lowest operant rate under RR1, although this was not the case in the present experiments. However, as Schoenfeld and Cole (1972, p.146) have pointed out, under RR1 (with a simple operant) there are only postreinforcement pauses, and this would complicate any consideration of response rate. Due to the nature of the operant this was not the case in the present experiment.

The distribution of 'errors' showed no systematic effect other than a tendency to make fewer 'errors' in the first two components. Davidson and Osborne (1974) also found no systematic 'error' pattern on a matching-to-sample task maintained by a VR schedule using children as subjects. As in the case of the FR (drl) experiment reported in Chapter 3, this has implications for a view of the role of the reinforcing stimulus in maintaining and controlling behaviour.

In the present experiment, the controlling function of the reinforcer (the consequence effect) is small with respect to the maintaining function (the antecedent effect), and there is not the gradual transition between the two that characterised the FR (drl) experiment. There seems to be maintenance of the (drl) behaviour throughout the whole of the interreinforcement interval, (after the short postreinforcement pause), and the change from controlling to maintaining function appears to be sudden.

The maintained component behaviour was not immutable, however, since decreasing the probability of reinforcement increased component duration. This is a clear demonstration of an interaction between the overall and component schedules, an effect occasionally mentioned (cf. Marr, 1969) but rarely demonstrated.

The absence of brief stimulus conditions makes difficult a comparison of this schedule with other second-order schedules, but despite several reports to the contrary, the present experiment shows quite clearly the possibility of maintaining 'typical' component behaviour without S^N or S^P. In fact, behaviour under RR8(drl), where as many as 20 consecutive components were emitted for a single reinforcement, was more akin to typical DRL behaviour (cf. Kramer and Rilling, 1970) than some studies using a simple DRL schedule (cf. Kramer and Rodriguez, 1971).

In many respects, changing the probability of reinforcement affected the complex operant in this experiment as it affects simpler operants, but again there is a scarcity of detailed information as to the control of simple operants under RR schedules of reinforcement.

GENERAL DISCUSSION

An explanation offered in both chapters for the effects on component behaviour of manipulating the ratio value was in terms of the two functions of the reinforcing stimulus. One function, it was suggested, is to maintain the behaviour upon which the stimulus is contingent. This is the usual effect inherent in the definition of a reinforcer as a stimulus which increases the future probability of preceding behaviour. The second function is to control the behaviour which follows it. This controlling effect is less well understood, although recognition of its importance is inherent in discussions of the reinforcer as a discriminative stimulus (cf. Reid, 1958), and in the distinction made between 'temporal' and 'situational' control by Staddon (1972; 1974).

Since Staddon's use of the term "temporal control" is mentioned often in this thesis, it is defined here:

> "...if Event A (a stimulus) occurs at a certain point in time and can be shown to determine the time of occurrence of Event B (a response) which occurs at a later point in time, the label temporal control is proposed for the relationship - no matter what the events A and B, no matter how long or short the time separating them, and no matter what other contextual dependencies may exist" (Staddon, 1972, p.213).

The terms 'maintaining' and 'controlling' are those used by Hendry (1969), and are preferred by the present author since their use does not assume any underlying processes, nor are they tied to particular theoretical frameworks.

It is not assumed here that the pairs of terms controlling-maintaining; discriminative-reinforcing; and temporal-situational are exactly synonomous but that, broadly speaking, they each make the same functional distinctions.

The proposal here is that the two effects work in the present situation as follows. The behaviour 'maintained' is DRL behaviour, which is generally characterised by a bi-modal IRT distribution, therefore generally incorporating 'errors'. What is 'controlled' is the postreinforcement pause. Some recent work by W.N. Schoenfeld and his co-workers (Schoenfeld and Farmer, 1970) has addressed itself to the problem of the topography of behaviour during the postreinforcement pause. (see also Terrace, 1974).

On a simple FI schedule, for example, the reinforcing stimulus maintains lever-pressing, but it also controls pausing, and there is a gradual transition between the two effects which is seen as a 'scalloped' pattern of responding. The controlling function is apparently determined mostly by the temporal characteristics of the schedule (cf. Staddon, 1972; 1974). With a fairly constant interreinforcement interval, the duration of the controlled behaviour becomes relatively constant, and the transition from controlling to maintaining functions is more marked, resulting in break-and-run behaviour (cf. Schneider, 1969).

The maintaining function of the reinforcer is also determined, at least in part, by temporal characteristics of the schedule, since decreasing the reinforcement frequency also decreases the rate of responding.

Staddon and Simmelhag (1971) have made the same point in a rather different way. They showed that there are two types of behaviour which can be identified in the steady state condition. One is the interim behaviour which occupies the time not spent emitting the terminal response, upon which reinforcement is made contingent by the experimenter. By detailed observation of FI, fixed-time (FT), and VI schedules, they showed that the interim behaviours vary greatly between subjects, but for each subject they occur in a fixed sequence before transition to the terminal response. Furthermore, they found that the variability of these interim behaviours decreased as time since food increased - there was a transition to the fixed and unvarying terminal response. This seems to mirror the transition between maintaining and controlling effects hypothesised in the present situation.

The formulation of controlling and maintaining effects appears to be simple, but consideration of other experimental data reveals factors in the situation which pose problems. For example, what exactly is maintained on simple schedules? In a typical FI schedule, the force with which the lever is pressed increases as the availability of reinforcement approaches (Gollub and Lee, 1964; Haney, 1972), although the contingencies specify only that a response with a certain minimum force be emitted. The same effect is obtained under FR schedules (Mintz, 1961). One theory holds that there is a high running response rate on FR schedules due to the selective reinforcement of short IRTs (Ferster and Skinner, 1957), although the schedule contingencies do not specify any particular IRT duration. (cf. Reynolds and McLeod, 1970). Davison (1969) has shown that IRTs get shorter during the interreinforcement time on a simple FR schedule and under FR (FR) schedules. This effect is not so pronounced on FI schedules (Shull and Brownstein, 1971). Moreover, there appear to be important species differences in this area (Davey, 1975).

These few examples illustrate some of the complexity involved in a "simple" schedule, where a single behavioural characteristic is chosen as the operant requirement, yet other aspects of the behaviour also vary functionally. The problem of specifying the maintained and controlled behaviour in many instances, then, is intimately tied in with questions about the nature of the operant. Section II of this thesis deals more fully with these questions, and attempts to clarify the notions of maintaining and controlling with respect to the issue of the nature of the operant.

Notterman and Mintz (1965) have also emphasised the necessity of examining many more facets of behaviour than psychologists generally consider.

> "Measures of behavioural variability and the relationship between the criteria for reinforcement and the response populations that they generate are among the data that may be no less fundamental to the dynamic laws of the operant than rate of response. We must not only ask "what rate?", but also "rate of what?" Within the operationally defined generic class of the "occurrence" type of response, readily identifiable dimensional subclasses exist". (pp.3-4).

The two experiments reported in this Section indicate that examination of the "subclasses" advances our understanding of the schedule control of complex operants in the same way that Notterman and Mintz (1965) advanced our understnading of the schedule control of simple operants.

'Errors' have frequently been mentioned in the preceding pages, and the question was raised of the comparability of 'errors' on DRL schedules, and 'errors' in other situations. It was suggested that non-criterion responses constitute a 'normal' part of DRL behaviour, whereas organisms may be trained to emit other complex operants without errors (cf. Terrace, 1966). Interresponse times less than 2 sec duration (bursts), for example, are 'errors' but are commonly found on DRL schedules and have been implicated in the timing process (cf. Ferraro et al. 1965).

Bigelow (1969) has suggested that time-consuming operants might magnify certain characteristics of schedule control not apparent with more instantaneous operants. He suggested that the 'scalloped' pattern of complex operants under FR may be attributable to such magnification, rather than, as suggested in this thesis, to the interaction between maintaining and controlling functions brought about by the temporal characteristics of the schedule. Both of these accounts are theoretical, and there is no evidence on which to decide between them, but it seems that Bigelow's explanation appeals to more unknown factors than does the view presented here.

The major behaviour changes found in both experiments were not reflected in measures of the overall rate of lever pressing. That this should be so was not unexpected, since the operant was not a simple lever press but a (drl) component. Response rate was examined, however, since it might occasionally give information about the 'subclasses' discussed by Notterman and Mintz (1965), and, as shown in the review of the literature on second-order schedules (Chapter 2), previous experimenters have reported systematic response rate changes with changes in second-order schedules. With a DRL operant, however, the 'bursts' of responding complicate the rate measure. This also contributed to the irrelevance of response rate measures in the present studies.

It appears that responding maintained on a DRL schedule in turn behaves in many ways similar to commonly studied simple operants when reinforced according to FR and RR. The (drl) component was free to vary in many ways, this variability being affected by changing the parameters of the overall schedule. However, there are also aspects of simple operants which vary with changes in the parameters of the schedule (Notterman and Mintz, 1965), and when these effects have been fully investigated, there may be even more correspondence between the schedule control of simple and complex operants than is at present obvious.

SECTION II

ON THE NATURE OF THE OPERANT

In this Section, three experiments are reported, the results of which appear to bear on questions concerning the nature of the operant, and the effect on schedule control of the characteristics of the operant.

The first experiment (Chapter 5) was an investigation into the nature of lever presses which are not recorded as responses since they are emitted with insufficient force. In Chapter 6, the value of the operant requirement was changed on a second-order FI (drl) schedule, and the effects of this manipulation were examined. Chapter 7 concerns a detailed examination of the behaviour pattern maintained by a DRL (drl) schedule.

CHAPTER 5

On the nature of sub-criterion responses

In many experimental situations, some of the depressions of the lever do not satisfy the force requirement, and are consequently not recorded as responses. Nevertheless, the animal has "pressed" the lever, and it may be important to ask

> "...are there significant experimental or theoretical questions best answered by examination of the dimensional characteristics of the response itself rather than by the study of the time interval between responses?" (Notterman and Mintz, 1965, p.3).

Notterman and Mintz are not suggesting that the time interval between responses is not a useful datum, but that it may not be the most important in all circumstances.

> "...it does not follow that measurement of force per se uniformly provides the scientist with the most useful source of information in any given experiment" (p.5).

METHOD

Subjects

Two naive, male, hooded rats (C-3 and C-4) served. They were 200 ± 20 days old at the start of the experiment. They were maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available in the home cage.

Apparatus

A standard experimental chamber was used. The lever was modified by the addition of a hair-spring[•], and by increasing the gap between upper and lower contacts from 0.3 cm to 0.6 cm (see Figure 5:1). The spring was positioned 0.1 cm above the lever, so that even very slight movements of the lever were recorded. The same force (0.1N) as on a conventional lever was needed to depress this modified lever - since the friction at the bearings was negligible - although the *work* needed (in the physical sense, cf. Notterman and Mintz, 1965, p.5) was greater.

[•] A spring was chosen as the contact since it returned to the same position after each lever press.

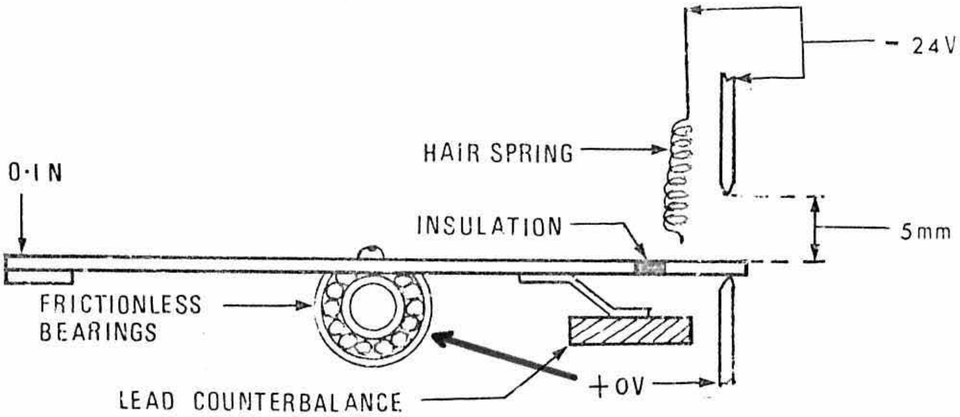


Figure 5:1

A schematic representation of the modified lever.

Procedure

Lever training was followed by exposure to DRL 20-sec for both subjects. Subject C-3 performed for 102 sessions, C-4 for 71 sessions. Sessions were conducted six days each week, and were of one hour duration.

RESULTS

The data presented is taken from the final two sessions. Different records were taken on alternate days. One day, the times between each lever press, including those which were not recorded as responses, were collected, and the next day, only the times between those presses which were recorded as responses were collected. Partial presses will be denoted as ~ R, so the times between instances of R, and between instances of (R+~R) have been analysed.

Figure 5:2 shows a comparison of the frequency distributions and conditional probability distributions of the IRTs and I(R+~ R)T's. The distribution of IRTs Erratum(ii) was skewed towards much shorter longer IRTs than were specified

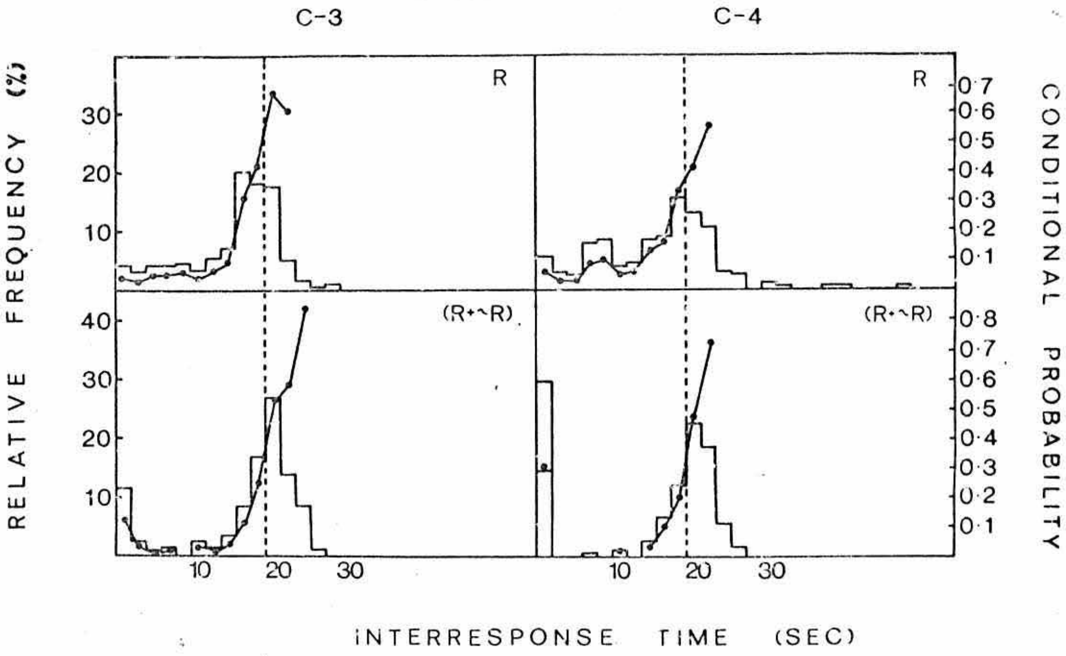


Figure 5:2

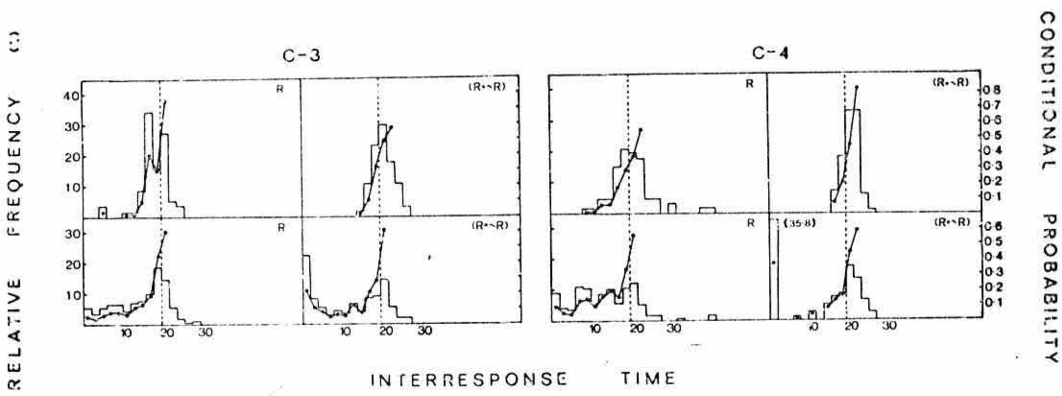
A comparison of the relative frequency and conditional probability distributions of all the interresponse times (IRTs) and inter lever-press times (I(R+~R)Ts).

by the DRL contingency. The I(R+∼R)T distributions, however, were centred around the required response criterion. There were also more 'bursts' when (R+∼R) were considered.

The distributions of R's and (R+∼R)'s following a reinforcement and following a non-reinforced R or (R+∼R) are compared in Fig. 5:3. For both subjects, after reinforcement there was a long IRT or I(R+∼R)T, but the distribution was more closely centred around the DRL 20-sec requirement when all lever presses were considered. Similarly, after a non-reinforced response, the next response was likely to be just short of the DRL requirement, whereas after a non-reinforced lever-press, the next lever-press was likely to be either a 'burst' or one satisfying the DRL criterion.

DISCUSSION

The results show quite clearly that the distribution of behaviour was more similar to that normally found under DRL contingencies (cf. Kramer and Rilling, 1970) when all lever presses were



Figures 5:3

A comparison of the relative frequency and conditional probability distributions of the interresponse times (IRTs) and inter lever-press times (I(R+~R)Ts) following reinforcement (upper half), and following non-reinforcement (lower half).

considered. There is an apparent anomaly here, since there were no scheduled consequences for many of the lever presses, yet the pattern of behaviour was very similar to that obtained under DRL schedules where every lever press has a scheduled consequence. The paradox is resolved, however, by an examination of the formal and historical characteristics of the concept of the operant.

Both Staddon (1967) and Catania (1973 a) have pointed out that the origin of the concept of the operant lies in Skinner's early papers dealing with the reflex (Skinner, 1931; 1935). These papers are important because they suggested a re-definition of the reflex - a term which had been in use for centuries - in terms of the relationship between behaviour and environment.

> "The essence of the description of behaviour is held to be the determination of functional laws describing the relationship between the forces acting upon, and the movement of, a given system. The reflex is, by definition, the precise instrument for this description". (Skinner, 1931, reprinted in Skinner, 1972, p.457; emphasis added).

Skinner (1972) has admitted that this statement was far too rigid to be of much use in discussing physiological reflexes, but in later works, the essence of this statement was retained in defining the operant.

> "An operant is a class of which a response is an instance or member...it is always a response upon which a given reinforcement is contingent, but it is contingent upon properties which define membership in an operant. Thus a set of contingencies defines an operant". (Skinner, 1969, p.131).

As Staddon (1967) has pointed out

> "...examination of the historical antecedents and formal characteristics of the concept of the...operant indicates that its <u>only essential property</u> is the embodyment of a causal relation between environment and behaviour" (p.382; emphasis added).

Catania (1973 a) suggested that, although the original definition of the operant was relatively clear, psychologists today seem to have two distinct uses of the term. One is the <u>descriptive operant</u>, which is usually to be found in the methodological section of experimental reports. It specifies the characteristics of behaviour which will produce reinforcement. The other type of operant is a <u>functional operant</u>. This is more akin to Skinner's original definition, and describes the response class which actually has been modified by its consequences.

Herein lies the solution to the paradox mentioned at the start of this Discussion.

The descriptive operant, specified by the experimenter beforehand, may not be identical to the functional operant, which is necessarily <u>inferred</u> from the behaviour maintained by a particular set of contingencies. Where the difference is very noticable, there is said to be a breakdown in schedule control. As Staddon (1967) pointed out, the recognition of a functional operant depends

> "...upon the insight of the experimenter" since "...a defining property cannot be operationally defined in advance". (p.379)

One further point remains to be clarified before these concepts may be applied to the experiment reported here. The definition of the operant mentions the identification of "dynamic laws" and "orderliness" in behaviour. Both Schick (1971) and Staddon (1967) have pointed out that Skinner has failed to specify exactly what is meant by "orderliness", and this is often considered to be a failing. However,

> "...such a specification is unfeasible since the usefulness of any construct is usually judged in relation to the theoretical system of which it is a part and not according to a priori notions of smoothness of curves...By leaving

> 'orderly' undefined, Skinner evaded the trap of specifying the laws of behaviour in advance of their discovery...At best the 'orderliness' criterion can be considered a fruitful heuristic which is frequently helpful in enabling us to make sense of data; at worst it has obscured invariances which do not conform to a preconceived form. The general problem of finding 'the natural lines of fracture along which behaviour and environment actually break' (Skinner, 1938, p.33) still remains". (Staddon, 1967, p.379).

In the context of the present experiment, "orderliness" may be assumed when the obtained pattern of behaviour is similar in many respects to the pattern generally obtained under those contingencies. (This point is elaborated in the General Discussion to Section II).

Kramer and Rilling (1970), in an extensive review of DRL schedules, showed that the typical frequency distribution obtained under DRL is bi-modal, with one mode at very short (0-2 sec) IRTs, and the other at the IRT value specified by the schedule. In the present experiment, the frequency distribution of all lever presses fits this pattern more closely than the frequency distribution of responses. It follows, then, that although responses were members of the descriptive operant class, lever presses ($R+\sim R$) were members of the functional operant class, and it was they, rather than responses, which were under the control of the contingency.

Hemmes (1970) has shown that DRL efficiency depends on the nature of the operant, and so it seems to be the case in the present experiment. Her subjects were pigeons, who are known to perform poorly on DRL schedules (cf. Staddon, 1965). She showed that when a topographically different operant was chosen (treadle pressing), then the pigeons were much more efficient than with a key-pecking operant. Similar differences in performance with different operants have been observed with the responses of rats on free-operant avoidance (Reiss, 1971); the phenomenon of behavioural contrast in pigeons (Hemmes, 1973); and the behaviour of rats under conditions of both signalled and unsignalled avoidance (Ayres, Benedict, Glackenmeyer and Matthews, 1974).

These studies place emphasis on topographically different responses, whereas the finding of the present study is that DRL efficiency can also depend on the dimension of the operant. In the present experiment, the topographies of R and $(R + \sim R)$ were very similar, but

> "...the topographical characteristics of the response class have no necessary relevance to the operant" (Staddon, 1967, p.383).

It seems that a case may be made for the assertion that the science of behaviour should be concerned mainly with the search for and an understanding of functional as opposed to descriptive operants.

There were two other influences in the present situation which might have had an effect on the patterning and nature of the behaviour.

The only behaviour to be followed immediately by reinforcement was a response (R). It was quite possible, however, for a non-response lever press to have just occurred ($\sim$R), therefore reinforcing a short I(R+$\sim$R)T. Also, a $\sim$R could be emitted which was more than 20 sec after the previous R, and it would not be followed by reinforcement. These two factors would presumably have some effect, but exactly what that effect might be it is not possible to tell within the limits of the design of the present experiment. Presumably, however, these effects could be acting in any schedule situation involving operant sub-classes. Those studies that have examined related dimensions of the response (cf. Davis and Burton, 1974; Haney, 1972; Mintz, 1962; Notterman and Mintz, 1965) have found that these, generally unrecorded aspects of the response are members of a functional operant, and are thus worthy of study. The results of the present experiment are very much in accord with this conclusion.

CHAPTER 6

Changing the (drl) requirement under FI (drl)

Both of the experiments reported in Section I demonstrated that the characteristics of the control exerted by the overall schedule could be modified by the characteristics of the operant, but no conclusion could be reached regarding the effect of different operants on an unchanging overall schedule. This experiment is an investigation of this problem.

METHOD

Subjects

Three albino rats and one hooded rat served. One of the albino rats (C-4) had an extensive history of responding under DRL 20-sec (Chapter 5). The hooded rat (A-1) had a history of responding on FI (drl) in a series of experiments which terminated nine months before the start of the present experiment. The two remaining albino rats (D-1 and D-2) were naive at the start of the experiment.

The two naive animals were 120 ± 20 days old at the start of the experiment, C-4 was 300 ± 30 days old, and A-1 was in excess of 18 months old. All rats were maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage.

Apparatus

The standard experimental chamber was used.

Procedure

Subjects D-1 and D-2 were first trained to lever-press, and then given 50 reinforcements under a continuous reinforcement schedule. All subjects were then exposed to a second-order schedule; FI 2-min(drl 20-sec) for A-1 and D-1, and FI 2-min (drl 10-sec) for D-2 and C-4.

After a minimum of 30 sessions, when the stability criteria had been satisfied, subjects A-1 and D-1 were exposed to FI 2-min (drl 10-sec), and subjects D-2 and C-4 to FI 2-min (drl 20-sec). The number of sessions for each subject is shown in Table 6:1.

RESULTS

Figure 6:1 shows the frequency distribution of IRTs, with the conditional probability distribution, for each subject, under both conditions. Both of the animals with (drl 10-sec) components showed temporal discrimination, to the extent that most of their IRTs were greater than 10 sec duration. The distribution had a peak at 10 sec in both cases, although for D-2 the highest probability occurred at 12 sec. The high proportion of very long IRTs for these subjects indicates the long postreinforcement pauses made under this schedule. D-2 had very few IRTs in the 0-2 sec range (bursts). When the operant was changed to (drl 20-sec), both rats adjusted the spacing of their responses to suit the new requirement, although D-2 was not as efficient as C-4 - the modal IRT occurred between 16 sec and 18 sec as opposed to between

TABLE 6:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
A-1	FI2-min(drl 20-sec)	81
	FI2-min(drl 10-sec)	40
D-1	FI2-min(drl 20-sec)	76
	FI2-min(drl 10-sec)	38
D-2	FI2-min(drl 10-sec)	71
	FI2-min(drl 20-sec)	46
C-4	FI2-min(drl 10-sec)	43
	FI2-min(drl 20-sec)	52

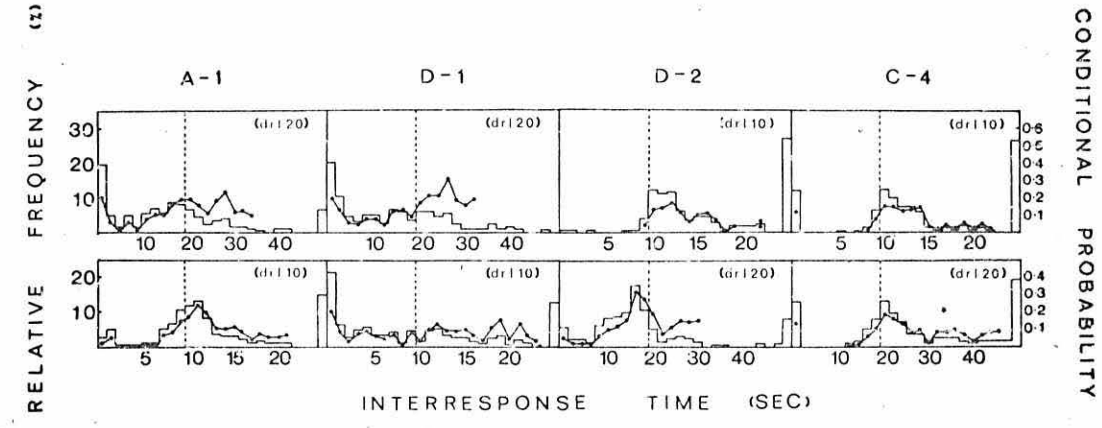


Figure 6:1

The relative frequency and conditional probability distributions for each rat under both conditions.

20 sec and 22 sec. The conditional probability distributions in each case reflected the IRT frequency distributions, although there was a further increase in the probability after the decrease just later than 20 sec. The number of 'bursts' made by D-2 increased under this condition, and the proportion of very long IRTs decreased for both animals.

Both of the rats started on FI 2-min(drl 20-sec) showed less differential responding than did their counterparts. That A-1 was responding according to the (drl) requirement is evident from the conditional probability distribution, which has a mode around 20 sec, followed by another mode between 28 sec and 30 sec. The probability of making a response also rose after 20 sec for D-1, reaching a peak between 26 sec and 28 sec. For both subjects, however, temporal discrimination with respect to the (drl) requirement was poor, with a high frequency of bursts in both cases. On decreasing the operant requirement from (drl 20-sec) to (drl 10-sec), A-1 showed a great improvement in efficiency, with a mode of both the IRT distribution and the conditional probability distribution occurring at 11 sec. D-1, however, showed no improvement and did not demonstrate any temporal discrimination. Both subjects showed an increase in the number of very long IRTs.

Table 6:2 shows the mean and median postreinforcement pause for each subject, along with the mean and median of the duration of the interreinforcement interval. Also shown is the interquartile range for each median. On changing the operant from (drl 20-sec) to (drl 10-sec), the postreinforcement pause increased, and the interreinforcement interval decreased. On changing from (drl 10-sec) to (drl 20-sec), the postreinforcement pause decreased, while the inter-reinforcement interval increased.

Figure 6:2 shows the effect of manipulating the value of the operant on the mean duration of each (drl) component within the interreinforcement interval. One noticeable effect was a decrease in the number of components emitted on changing from (drl 10-sec) to (drl 20-sec), and an increase on changing from (drl 20-sec) to (drl 10-sec). With the exception of D-1 under FI 2-min(drl 20-sec), all animals under all conditions showed a decrease in the mean duration of the components as time from the last reinforcement increased. In the case of D-1 under FI 2-min (drl 20-sec), after the first component, each subsequent component was of approximately the same duration.

TABLE 6:2

Mean and Median Postreinforcement Pause and Interreinforcement Interval Durations. Interquartile Ranges Shown in Parentheses.

		POSTREINFORCEMENT PAUSE DURATION (sec)		INTERREINFORCEMENT INTERVAL DURATION (sec)	
SUBJECT	SCHEDULE	MEAN	MEDIAN	MEAN	MEDIAN
A-1	FI2-min(drl 20-sec)	50	55(26-73)	165	135(127-200)
	FI2-min(drl 10-sec)	60	61(40-74)	135	126(120-130)
D-1	FI2-min(drl 20-sec)	30	30(22-33)	150	139(128-165)
	FI2-min(drl 10-sec)	45	46(28-58)	132	129(124-132)
D-2	FI2-min(drl 10-sec)	65	66(48-76)	125	124(121-127)
	FI2-min(drl 20-sec)	59	62(29-75)	201	164(131-207)
C-4	FI2-min(drl 10-sec)	72	71(49-92)	128	125(121-130)
	FI2-min(drl 20-sec)	63	66(37-80)	138	137(127-143)

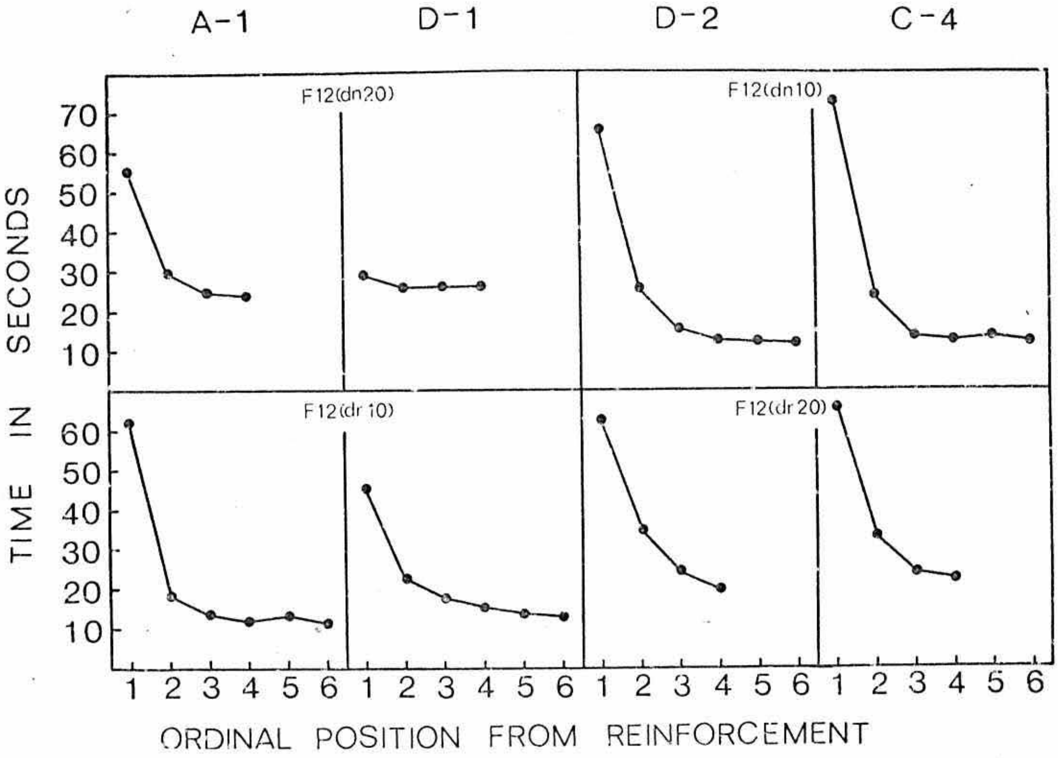


Figure 6:2

The mean duration of each IRT satisfying each of the (drl) components within the interreinforcement interval.

Three rate measures are presented in Fig. 6:3. On changing from (drl 20-sec) to (drl 10-sec), the overall response rate decreased for one rat, and increased for the other. The same inconsistentcy was evidenced on changing from (drl 10-sec) to (drl 20-sec), with one rat making more responses, and the other rat making fewer. The changes in rate of emission of operants, was, however, more systematic. The overall operant rate increased as the (drl) value decreased, and decreased as the (drl) value increased. The same relationship held for operant running rate, but the function was even more marked.

Sample cumulative records are shown in Fig. 6:4. A 'scalloped' pattern of responding was evident for all subjects, being more pronounced when the operant was (drl 10-sec).

DISCUSSION

As in the experiments reported in Section I, the overall response rate has been shown to be an inappropriate measure for studies of complex operants. The operant rates, however, showed consistent effects on changing the value of the operant, but this could

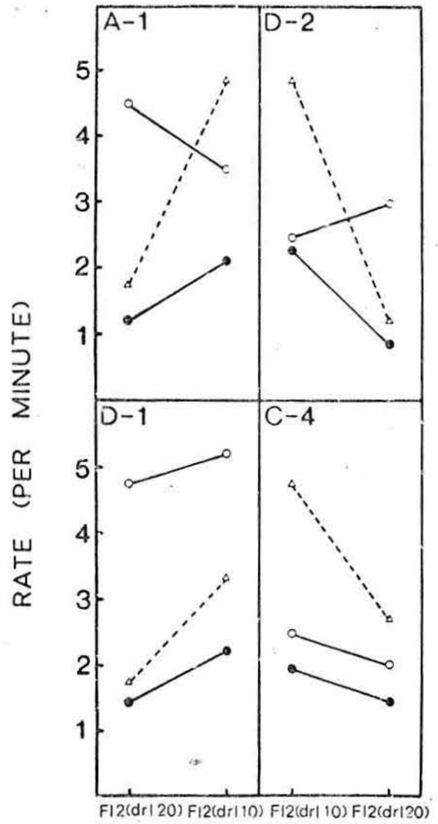


Figure 6:3

The rate measures. The open circles represent the overall rate of lever-pressing, the closed circles represent the overall rate of emission of (drl) components, and the triangles represent the running rate of (drl) components.

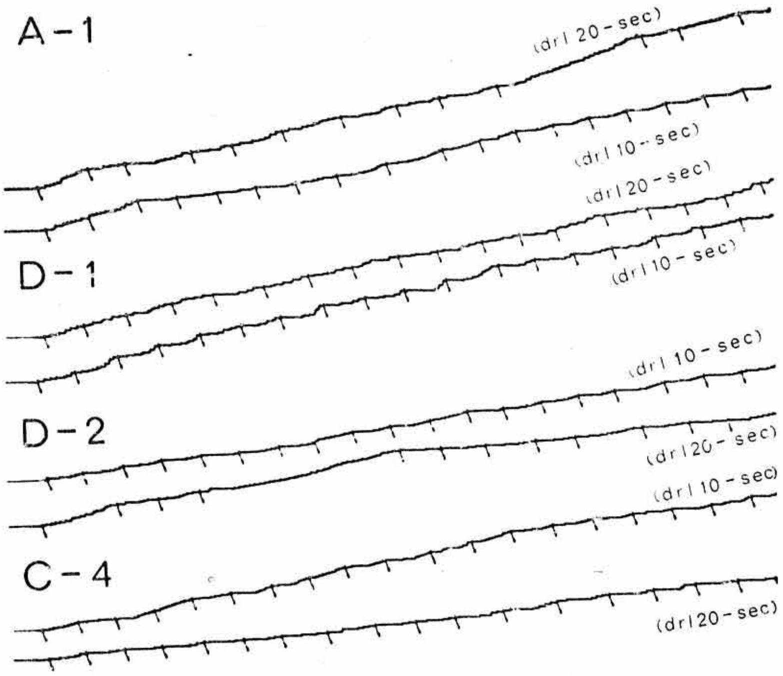


Figure 6:4

Sample cumulative records, taken from the final session under each condition.

easily have been due to the doubling or halving of the number of opportunities to emit the operant in a session, as a result of changing the operant requirement.

The frequency distributions and conditional probability distributions of IRTs showed that, in most cases, the rats were discriminating the required duration of the operant. Put another way, they were responding differentially with respect to the time since the last response. It appears that temporal discrimination and response differentiation are two ways of describing the same behaviour, and the only difference between them is a verbal one (cf. Catania, 1970). This issue is discussed at greater length at the end of Section II.

The accuracy of the behaviour was obviously much better for the two subjects who started with (drl 10-sec) components. A high percentage of their responses conformed to the temporal requirements of the operant class, whereas the IRTs of those subjects starting with (drl 20-sec) components were spread widely around the criterion. Only for one rat on FI 2-min (drl 20-sec) was there any evidence of an increase in response probability at or around the (drl) value. On changing the requirements, the two who were efficient on (drl 10-sec) became reasonably accurate on (drl 20-sec), although one rat had the highest response probability just before the criterion.

For one of the rats showing poor temporal discrimination with a (drl 20-sec) component, changing the requirement simply decreased the amount of differentiation. The other animal (A-1) improved slightly in efficiency. Since it is clear that animals <u>can</u> respond accurately under FI 2-min (drl 20-sec) an explanation of the poor behaviour of A-1 and D-1 may lie in the order in which the conditions were presented. It might be easier to emit a "hard" response (such as (drl 20-sec)) if there is first training with an "easier" one (say, (drl 10-sec)). This may have been the case with D-2 and C-4. Furthermore, if a rat is first given a "hard" task, this may jeopardize his chances of later coming under the control of an "easier" one. This may have been the case with A-1 and D-1.

This speculative and anthropomorphic use of the terms "easy" and "hard" is connected with the distinction made in Chapter 5, and by Catania (1973, a and b), between functional and descriptive operants.

Catania (1973 b) gave an example of a rat who had to emit a behaviour which was too "hard" - placing its nose in a vertical slot which was too high for it to reach easily. Faced with this problem, the rat actually emitted a response which was only an approximation of the required behaviour; the descriptive and functional operant classes did not correspond perfectly.

In the present experiment, in most cases (for D-2 and C-4) the degree of correspondence was very high, but for A-1 and D-1, there was much less correspondence. A further set of experimental manipulations should be made in order to increase this degree of correspondence. One such set is reported in Chapter 10.

Typical FI behaviour is usually described as 'scalloped' (Ferster and Skinner, 1957) or break-and-run (Schneider, 1969). Cumulative records (Fig. 6:4) showed that the behaviour in the present experiment may be described as 'scalloped'. On FI schedules, however, the overall rate of responding apparently obscures a series of relationships between behaviours in different parts of the interval. One school of thought (cf. Schneider, 1969; Schneider and Neuringer, 1972) holds that a two-state model suffices to describe FI behaviour. Reinforcement is followed by a pause, and then there is a constant rate of responding to the next reinforcement, these two aspects of behaviour being separately determined. The postreinforcement pause is a more-or-less constant fraction of the interreinforcement interval. That this theory is too simplistic is evident from the findings of large variations between intervals in both postreinforcement pause and number of responses (cf. Dews, 1970), and by studies demonstrating the dependence of the running rate on the preceding postreinforcement pause (Davey, 1975; Harzem, personal communication, November, 1974).

This theory also does not account for the effects on postreinforcement pause of changing the operant in the present study, since Table 6:2 shows clearly that the postreinforcement pause was not a constant fraction of the interreinforcement interval. Furthermore, in the present study, the postreinforcement pause actually decreased with an increase in interreinforcement interval, and vice versa. Unless completely different variables affect the behaviour of simple and complex operants under FI schedules, the relationships uncovered in the present study cast doubt on any simple model of FI behaviour (also cf. Crossman, Heaps, Nunes, and Alferink, 1974; Dews, 1970).

The behaviour engendered by the FI(drl) schedule should be demonstrated to be similar to simple FI schedules. Figure 6:2 shows that, as reinforcement is approached, the mean duration of each component decreased, so that the reinforced component was very close in duration to the required value. In Chapter 3, a similar pattern of responding was described as a transition from the controlling to the maintaining function of the reinforcer. Within the framework of the present Discussion, there seems to be a gradual change towards the descriptive operant. This was the case even for D-2 under FI 2-min(drl 20-sec), where the IRT distribution suggested no temporal discrimination. The comparison between maintaining and controlling stimuli, and functional and descriptive operants is explored further in the Discussion to Section II.

Another comparison between the present schedule and simple FI exists in the finding that other dimensions of the lever-press change during the interreinforcement interval in a way which seems very similar to the changes in duration of the component in this study. The most obvious examples are force of responding (Haney, 1972), latency of response in discrete-trials FI (Heinz and Eckerman, 1974; Wall, 1965), and rate of response (Dews, 1970).

The point must be made, however, that there is no restricted set of defining conditions which classify any given sample of behaviour as FI. Although one may point out correspondences between behaviour under the present schedule and behaviour under simple FI, it is difficult to be able to say with complete confidence that any piece of behaviour is "typical" FI behaviour. This matter is discussed further at the end of Section II.

One of the main conclusions of the present report, is that it seems doubtful that any simple account of FI will suffice, certainly not for the present data. Schneider and Neuringer (1972) have even hinted at this while postulating the simple model, since they pointed out that, although the pattern of responding under discrete-trials FI is similar to that under free-operant FI,

> "...there were greater differences between subjects under the free-operant than under the discrete trials procedure" (p.197).

It is possible that the discrete trials situation is somewhat "artificial" in that there are constraints such that some factors cannot operate. This is not the case in a free-operant FI situation. Because of this, a very good 'fit' to the two-state model of responding under discrete trials FI should be interpreted cautiously.

The nature of the operant was certainly an important factor in the present experiment. Interactions between the overall and the component schedules were apparently so complex that one can but surmise possible relationships.

CHAPTER 7

On responding controlled by DRL (drl)

The schedules discussed in this chapter have the advantages of being completely novel, while adding to the discussion concerning the nature of the operant. In these DRL(drl) schedules, the overall and component schedules both specified spaced responding for reinforcement, and it is one of the purposes of this chapter to assess the "strategies" used by the animal in dealing with this requirement.

METHOD

Subjects

Four naive, male albino rats served. Each was maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage. At the start of the experiment, each of the animals was 250 ± 20 days old.

Apparatus

The standard experimental chamber was used.

Procedure

After lever-training and 50 reinforcements under a continuous reinforcement schedule, G-1 and G-2 were placed on a DRL 10-sec schedule, while G-3 and G-4 were placed on DRL 5-sec. When behaviour was stable (see p. 48), then G-1 and G-2 were exposed to DRL 30-sec (drl 10-sec), and G-3 and G-4 to DRL 30-sec (drl 5-sec) schedules.

The second-order schedule was programmed in exactly the same way as any conventional second-order schedule. Once the rat had made a lever press which satisfied the component schedule, then an output was given which served as an input for the overall schedule. If this input satisfied the criterion of the overall schedule, reinforcement was presented. If it did not, then the overall schedule timing clock was reset.

Similarly, if a lever press did not satisfy the criteria for the component schedule, then the component schedule timing clock was reset, although this, of course, had no effect on the overall schedule. ●

The number of hours under each condition is shown in Table 7:1. G-3 and G-4 were run on DRL 5-sec with sessions lasting 30 min.

RESULTS

Figure 7:1 compares the frequency distributions of IRTs, and the associated conditional probabilities, from the final sessions under both DRL and second-order DRL(drl). When the schedule conditions were changed, there was a marked shift in the distributions towards longer IRTs. In the case of G-2, there was also a very big increase in the proportion of 'bursts'. This biased the distribution in such a way that there were an insufficient number of IRTs to show a mode at around 30 sec, although there is a sharp rise in the conditional probability around this area. The distribution of IRTs for G-1, however, shows a mode around 30 sec.

● It was, of course, possible for the first lever-press after reinforcement simultaneously to meet both overall and component requirements, and thus be reinforced.

TABLE 7:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
G-1	DRL 10-sec	39
	DRL 30-sec(drl 10-sec)	49
G-2	DRL 10-sec	36
	DRL 30-sec(drl 10-sec)	46
G-3	DRL 5-sec	11
	DRL 30-sec(drl 5-sec)	54
G-4	DRL 5-sec	13
	DRL 30-sec(drl 5-sec)	60

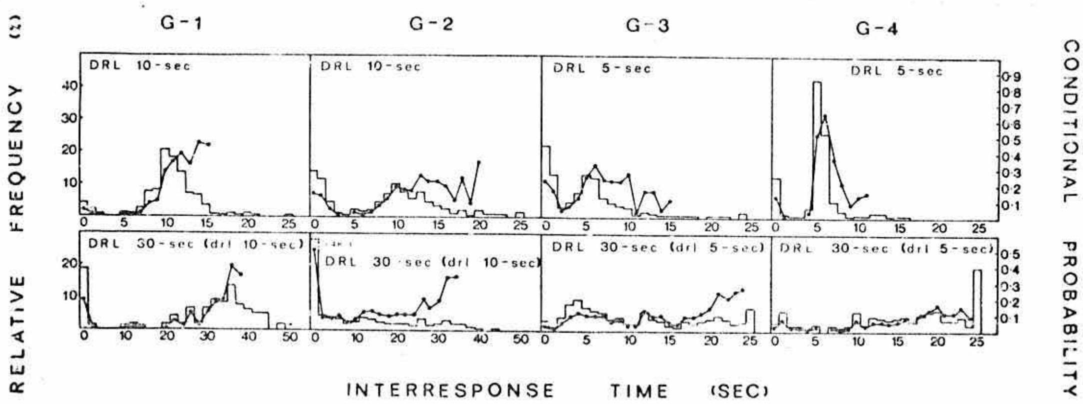


Figure 7:1

A comparison of the relative frequency and conditional probability distributions of the interresponse times from the DRL and the DRL(drl) schedules.

The distributions for G-3 and G-4 are much less clear, although there was a rise in conditional probability towards the long IRTs in the case of G-3, and G-4 made 25% of his IRTs longer than 25 secs.

By treating the component as an operant, it was possible also to record intercomponent time durations, and these are presented in Fig. 7:2. For both of the rats with (drl 10-sec) components, there was good correspondence between the DRL 30-sec requirement, and the actual intercomponent time distributions. G-1 made most of his components at least 30 secs apart, while in the case of G-2, there was a marked increase in the conditional probability distribution after 30-sec.

The temporal distribution of components, fell short of the 30 sec specified by the overall schedule in the case of both of the rats with (drl 5-sec) operants.

Since there are two distinct response consequences under DRL (reinforcement and resetting the clock), then one may examine separately, the distribution of components following each of these events. Table 7:2 shows the median intercomponent time, with its inter-

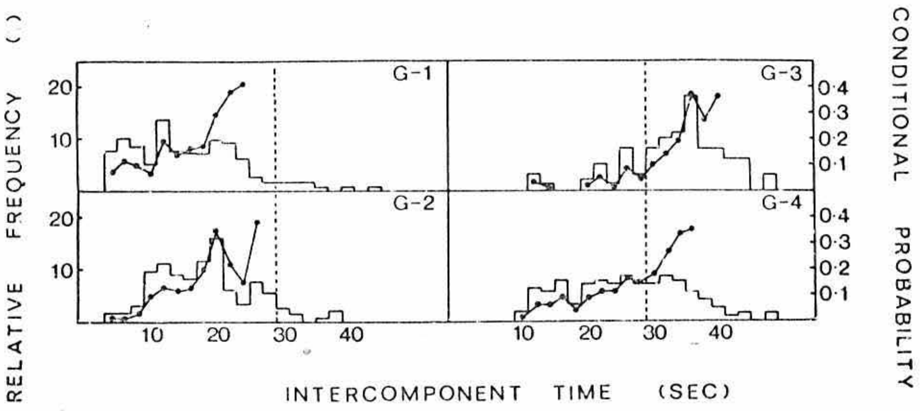


Figure 7:2

The relative frequency and conditional probability distributions of the intercomponent times under the DRL 30-sec(drl) schedules.

TABLE 7:2

Comparison of the Duration of the Component following a Reinforcement and Following a Nonreinforcement. Figures are Medians; Interquartile Ranges shown in Parentheses (sec).

SUBJECT	SCHEDULE	AFTER REINFORCEMENT	AFTER NONREINFORCEMEN
G-1	DRL 30-sec(drl 10-sec)	37(33-40)	26(22-32)
G-2	DRL 30-sec(drl 10-sec)	33(28-37)	22(16-28)
G-3	DRL 30-sec(drl 5-sec)	21(17-24)	12(6-18)
G-4	DRL 30-sec(drl 5-sec)	24(21-30)	18(12-22)

quartile range, following a reinforcement and following a non-reinforced component. For all rats, reinforcement was followed by a longer intercomponent time than was non-reinforcement, and for G-1 and G-2, this was generally long enough to satisfy the overall schedule requirement. This was not often the case for G-3 and G-4.

DISCUSSION

Consideration of the temporal distribution of components (Fig. 7:2) shows that the rats with (drl 10-sec) operants were more under the control of the DRL 30-sec contingency than were the subjects with (drl 5-sec) components. This conclusion is also supported by the analysis presented in Table 7:2. It is also clear, however, that the behaviour of G-3 and G-4 was <u>to some extent</u> under the control of the overall schedule, since there was an increasing probability of emitting a component between 20 sec and 30 sec, and there was a distinct difference between the intercomponent times following a reinforced component and a non-reinforced component. It seems pertinent to consider the factors which may be responsible for the poor temporal control of the overall schedule with (drl 5-sec) as opposed to (drl 10-sec) components.

One possible factor may have been the control exerted by the component schedule. In the case of (drl 5-sec), the control may be thought of as very 'powerful', since the time interval involved is very small. It is well documented that efficiency under DRL decreases as the time requirement is increased (cf. Richardson and Loughead, 1974). On the other hand, the control exerted by the (drl 10-sec) schedule may have been less rigid. On changing to the second-order schedule, the less-rigid control may have been much easier to change, and consequently the DRL 30-sec schedule could come to control the behaviour.

Although this explanation is intuitively plausible, it relies for some of its value on such ill-defined terms as "rigid control", and is thus scientifically valueless without more empirical evidence and clear, operationally-defined terms. Such evidence might take the form, for example, of experiments attempting to show that (drl 20-sec) components come under better control than do (drl 10-sec) components within this paradigm. Until such evidence is forthcoming, then the mechanisms of schedule control will remain obscure, although this matter has interested several writers (cf. Ferster and Skinner, 1957; Schoenfeld, 1970; Staddon, 1972).

The two conditions of the present experiment may be discussed with relevance to the distinction drawn previously in this Section between functional and descriptive operants. The descriptive operant may be considered to be a completed component occurring at least 30 sec after the last such component, rather than simply (drl 5-sec) or (drl 10-sec). This is analogous to the consideration of the operant in simple DRL schedules as a lever press occurring at least x seconds after the last lever press, rather than simply any lever press (cf. Catania, 1970; 1973 b).

Following this line, G-1 and G-2 showed a good deal of correspondence between the functional and descriptive operants, whereas G-3 and G-4 showed very imperfect matches. Having formulated the problem in this way, the question of achieving the best form of control by the DRL (drl) schedule becomes one of increasing the correspondence between the functional and descriptive operants. One way of doing this is discussed in

Chapter 12 of this thesis.

No rate data have been presented in this chapter, because it is now widely acknowledged that rate of responding is not a good dependent variable for an evaluation of DRL behaviour (cf. Kramer and Rilling, 1970, p.230). Of interest in the DRL situation is the pattern, rather than the rate of responding. It has often been suggested that the term "differential-reinforcement-of-low-rate" is unsuitable since it places the emphasis on rate rather than patterning (cf. Kramer and Rilling, 1970; Morse, 1966).

The present schedule, as well as illuminating the distinction between functional and descriptive operants, also showed the usefulness of treating second-order schedules as schedules of complex operants. Within traditional second-order thinking, one is often tempted to guess at what the animal will do in any particular situation in order to, say, maximise reinforcement, or to minimise response effort. If the situation is considered as the reinforcement of a complex operant, one is brought 'back', so as to speak, to the situation of merely considering the data carefully, and then thinking of ways in which to bring the behaviour under better schedule control. It seems clear that a logical framework for the description of behaviour, and for the classification of environmental events, is a necessity for the study of complex behaviour.

GENERAL DISCUSSION

A recurrent problem in the three chapters of this Section has been one of establishing the behaviour generated by a particular schedule as an instance of 'typical schedule control'. In Chapter 6, for instance, in order to demonstrate the lack of value in a simple two-state model of FI responding, it was necessary to show that the FI(drl) schedule could, indeed, be classified as a FI schedule. The problem seems to be one of the identification of the necessary and sufficient conditions which would enable one to call a particular behaviour pattern by a specific schedule name. The same issue arose in Section I when deciding whether or not FR(drl) and RR(drl) constituted typical FR and RR behaviour.

Logically, to resolve this matter, there seem to be two pre-conditions. First, one must have an accurate characterisation of 'typical' schedule behaviour, and second, one must then be able to show that behaviour under the complex schedule in question may also be characterised in the same way. The situation is complicated, however, because rarely do we have an accurate description of the 'simple' schedule. A demonstration of this is that prediction of changes in response rate and running rate on manipulating the FR parameters is not possible because of a dearth of basic experimentation.

The concept of "schedule control" seems to be a disjunctive one, in the terminology of Bruner, Goodnow, and Austin (1956). The presence of a combination of a number of different attributes serves to classify any particular instance as a member of that concept. For example, behaviour might be said to be under FI control if a scalloped pattern is evident (Ferster and Skinner, 1957), or if "break-and-run" is evident (Schneider, 1969), or if there is a constant relationship between post-reinforcement pause and interreinforcement time (Schneider and Neuringer, 1972). This list is not exhaustive, but there clearly is a lack of such a list of defining attributes for any specific example of schedule control.

Another line of reasoning regarding schedule control has also been followed in the past. Any sample of behaviour is an example of FI behaviour if the contingencies of reinforcement are so arranged that the first response after a certain period of time from the last reinforcement is followed by reinforcement. This view concentrates on the descriptive operant, and diverts attention from what the organism actually does in a given situation. The emphasis in the present account is on the functional operant, and how it differs from the descriptive operant, and so is a synthesis of this latter view and the 'disjunctive concept' approach.

In Section I, a distinction was made between the controlling and maintaining functions of the reinforcer (cf. Hendry, 1969). The behaviour maintained by the reinforcer is also that upon which the reinforcer is contingent and so is often the descriptive operant. This point of correspondence between the two verbal distinctions serves to illustrate the contention of Findley (1962) that:

> "...the problems in establishing and analysing multi-operant behavours are... largely ones of definition, conceptualisation (and) description..." (p.114)

Catania (1969; 1970; 1973, a, b) has often pointed to the inaccuracies and inadequacies in our verbal behaviour when we discuss our experimental results. For example, in this Section the (drl) schedules have been described as showing temporal control or temporal discrimination. Catania (1970) suggested that the term "temporal discrimination" is one which is difficult to define, since it does not refer to the same manner of things as does "stimulus discrimination". We use the term when we are concentrating on temporal aspects of the experimental situation - the organism is said to be able to discriminate the time interval requirement, say, under DRL schedules.

Talking in this way often leads to suggestions, for example, that pigeons are inefficient on temporal discrimination tasks (cf. Staddon, 1965), which is not true as a general fact, but which is true in a particular experimental situation (the DRL schedule) with a particular response requirement (the key peck) (cf. Hemmes, 1970). Stubbs (1968) has shown that pigeons can discriminate quite accurately between different time intervals, and the very long post-reinforcement pauses on some FI schedules indicate that they often do come under very powerful temporal control (Dews, 1970).

There is also an alternative way of describing behaviour under DRL schedules. The time between responses may be considered as one of the defining characteristics of the operant class (cf. Morse, 1966; Reynolds and McCleod, 1970; Shimp, 1968; 1971). In this case, DRL behaviour may be described in terms of response differentiation.

Catania (1973 b) has made the point as follows:

> "...if a pigeon's key-pecks are reinforced only when they follow a 5 sec period of no pecking (DRL 5-sec), the pigeon may come to space its pecks about 5 sec apart. This performance may be spoken of as the differentiation of a complex operant consisting of a pause plus a peck. On the other hand, the duration of the pause may be treated as a stimulus property, and the performance may then be spoken of as discrimination with respect to the duration of the preceding pause.
>
> ...The distinction here involves the vocabulary with which we describe behaviour, and not the characteristics of behavioural processes. The operation of differential reinforcement underlies each of these cases.
>
> ...The fundamental issue...concerns the correspondence between the dimensions on which differential reinforcement is based, and the dimensions of the resulting behaviour". (pp.59-60).

It seems reasonable to suggest, then, that we should examine carefully the conditions under which we use terms such as "schedule control". If schedules of complex operants can be shown to correspond in several ways with the behaviour of simple operants, then the complex schedule ought to be taken into account when formulating theories of schedule control. The simple two-state FI model failed in this respect because it cannot handle cases such as the differences in behaviour of rats and pigeons under FI (Davey, 1975), nor the maintenance of complex operants under FI (cf. Chapter 6).

Section II has also emphasised the importance of measuring dimensions of behaviour other than the rate of lever-pressing. This is really another facet of the perennial problem in science of concentrating on too few dependant variables, and consequently missing other important relationships. Banesh Hoffman (1947) gave an example of this in the physical sciences. Discussing the part played by Hertz in the discovery of the quantum, he pointed out that Hertz was working within the classical model, and he was interested mainly in establishing the 'correctness' of Maxwell's theory. However, using that particular apparatus, if he had examined certain phenomena in greater detail, he could have pointed the way to an earlier transition to quantum theory.

> "In 1887 Hertz had noticed the curious fact that when ultraviolet light shone on his apparatus the sparks came more readily.
>
> Little could he realise that here within his grasp lay what still remains one of the clearest and most direct evidences we have for the existence of the quantum...The recognition of the quantum had to await the turn of the century, and when it came it was from a quite different quarter". (p.25)

This example is somewhat dramatic, but the principle is worth remembering. (For an example closer to psychology see Weisberg (1971)).

In the present experiments, it was necessary to monitor several aspects of the behaviour in order to obtain adequate functional relationships. It is quite possible that other, possibly more important, relationships exist which have not been identified because relevant dimensions of the behaviour - for example, response force - have not been examined.

The FI(drl) and the DRL(drl) shed some light on the effect on present behaviour of prior training. In the latter case it was suggested that the temporal control exerted by the (drl 5-sec) schedule is more resistant to change than that involved in (drl 10-sec) In the former experiment, it was suggested that responding with an operant of (drl 20-sec) is "easier" if the subject has first been trained on (drl 10-sec). Both of these hypotheses, while intuitively plausible, rely for proof of "correctness" on further experimentation.

This general area is involved, however, whenever one changes schedule contingencies, but the question is generally ignored unless the previous behaviour is found to be unobtainable on reversing the change, or, as in the present examples, animals with different operants reinforced according to the same overall schedule display different behaviours. The former case - that of irreversible changes - has been termed 'metastability' (Staddon, 1965). A recent experiment by Alleman and Zeiler (1974), in which the behaviour pattern under fixed-time schedules depended on the schedule to which the animal had previously been exposed, also demonstrates the importance of an understanding of these "history effects" for the analysis of behaviour.

That psychologists are becoming increasingly critical of some of the basic tenets of operant psychology is a relatively new phenomenon. This type of critical evaluation may be necessary, however, if we are to achieve a greater understanding of complex behaviour. Signorelli (1974) has compared modern psychology to Aristotelian physics, and has commented that

> "Considering the futility of experimentation that evolved from the Aristotelian philosophy... it would behoove psychologists to re-examine the influence of their procedures on the underlying philosophy of their science". (p.777)

Some of the procedures he criticised must include those which ignore aspects of behaviour other than rate. One of the conclusions to be drawn from this Section is that there are many more characteristics of the operant which influence behaviour than generally have been acknowledged.

SECTION III

THE EFFECT OF SCHEDULING BRIEF-STIMULI ON SECOND-ORDER SCHEDULES

> "One important question is whether the intermittent pairing of (a) brief stimulus and food is necessary for appropriate schedule performance to occur. Perhaps the presentation of any stimulus accompanying component completion would produce similar effects ...Do similar effects on response rate and response pattern occur under second-order schedules involving a paired stimulus and a non-paired stimulus?" (Stubbs, 1971, p.290).

Since the early recognition that some events could acquire properties they did not previously have by association with events having those properties, scientists have been concerned with establishing the necessary and sufficient conditions under which these phenomena occur. This has been a long-standing problem in science. Consider, for example, early experiments concerned with the transmission of 'magnetism'.

For the experimental analysis of behaviour, one problem of this sort has been the problem of conditioned reinforcement. It was known that food, given after a required response, would increase the future probability of occurrence of that response (cf. Thorndike, 1911). At the same time, Pavlov and his co-workers were finding that they could elicit similar responses with both a bell and food, provided the bell had been presented previously in the presence of food (Pavlov, 1927). If the presentations of food and bell together ceased, the bell gradually lost its eliciting properties, although the food did not. Furthermore, different methods of presenting the food and the 'neutral' stimulus resulted in different degrees of effectiveness of the bell as an elicitor.

Compiling these results, it soon became clear that previously 'neutral' stimuli should acquire similar properties to food - in that they too should be able to increase the probability of responses upon which they are contingent - if they are presented with food in an appropriate way. Much of the early history of psychology was concerned with investigating this phenomenon of conditioned or secondary reinforcement (cf. Hilgard and Marquis, 1940).

The procedures used in these early studies were either extinction or chaining procedures, and have been extensively reviewed by Kelleher and Gollub (1962), and by Wike (1966). A major experimental problem was the maintenance and establishment of durable conditioned reinforcers, and second-order schedules became a useful research tool in this respect (Kelleher, 1966 a; b).

It was necessary to establish conditions where the behaviour maintained by the 'neutral' stimulus could be compared with behaviour maintained by the primary reinforcer, but where the effects of the conditioned reinforcer were not waning due to lack of pairing with the primary reinforcer.

The first two Sections of this thesis have been directed at demonstrating that second-order schedules may be used for other, possibly more basic, aims in the analysis of behaviour. This Section is intended to show that this approach of treating second-order schedules as schedules of complex operants is also valuable to the study of conditioned reinforcement.

Five experiments are presented, but all have the same basic paradigm. The nomenclature and terms used in this Section were described in the Introduction.

Once responding on the baseline second-order schedule had stabilised, each completed component, except the one terminated by reinforcement, produced a brief tone, i.e. the non-paired condition (S^N) was in effect. After stability was achieved under this schedule, the final component in each interreinforcement interval also produced the tone, i.e. the paired condition (S^P) was in effect. After reaching stability under this schedule, the S^N condition came back into effect, and then finally the animal was placed onto the baseline DRL schedule, in order to assess any effect on the component behaviour of the extensive experimental history.

The apparatus was described in the Introduction to the experiments. The duration of the brief tone was always 0.75 sec. The intensity (loudness) of the tone was different for different experiments - details are given in the appropriate Chapter. Tones were produced by passing a 0.75 sec pulse of 100 Hz square-wave tone through an amplifier, and then into an 8 inch, 3 ohm speaker mounted on the inside door of the sound-attenuating chamber.

CHAPTER 8

Brief-stimulus manipulations on RR(drl)

The experiment reported here is an extension of that reported in Chapter 4. The final condition of that experiment was RR8(drl), and it is onto this baseline that the brief-stimulus manipulations were made.

METHOD

Subjects

Three male hooded, and one male albino rat served, each having had a prior history of responding under second-order schedules, as detailed in Chapter 4. None of them had previously been exposed to the stimulus. They were maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage.

At the start of the experiment, two of them (B-1 and B-2) were 240 ± 10 days old, while the other two (C-3 and E-5) were 330 ± 20 days old.

Apparatus

Each subject was run in the same standard experimental chamber in the same order each day. The brief stimulus used was 0.75 sec in duration, 100 Hz, and 80 ± 2 db in intensity. To a human observer, it was clearly audible above the noise (60 ± 2 db) of an exhaust fan.

Procedure

Sessions were one hour in duration, and were conducted 6 days each week. Each subject was run under each condition until the behaviour was stable. Each condition was in effect for at least 20 sessions, the number for each subject is shown in Table 8:1.

The order of conditions was tandem, S^N, S^P, and S^N, although for B-1 and B-2 there was no return to S^N after S^P.

After the final second-order schedule, each subject was run on a simple DRL schedule, corresponding

TABLE 8:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
B-1	RR8(drl 10-sec)	50
	RR8(drl 10-sec: S^N)	27
	RR8(drl 10-sec: S^P)	33
B-2	RR8(drl 10-sec)	52
	RR8(drl 10-sec: S^N)	28
	RR8(drl 10-sec: S^P)	36
C-3	RR8(drl 20-sec)	34
	RR8(drl 20-sec: S^N)	25
	RR8(drl 20-sec: S^P)	30
	RR8(drl 20-sec: S^N)	36
E-5	RR8(drl 20-sec)	40
	RR8(drl 20-sec: S^N)	24
	RR8(drl 20-sec: S^P)	27
	RR8(drl 20-sec: S^N)	26

to the value of the component to which the subject had been exposed.

RESULTS

Figure 8:1 shows the distribution of IRTs and conditional probabilities for each condition. There was little change evident on transition from tandem to S^N, but a considerable "sharpening" of the distribution on transition from S^N to S^P. This effect was most obvious in the case of the animals with (drl 10-sec) components, and least obvious for E-5. The effect was reversed for C-3 on changing back to S^N from S^P.

In this situation, there were three possible response consequences: (i) reinforcement, (ii) a completed component, followed by a brief stimulus in the S^N and S^P condition, and (iii) no feedback for an error (a response not satisfying the (drl) requirement).

Figures 8:2, 8:3, and 8:4 show the distribution of behaviour following each of these consequences. Figure 8:2 shows that for 3 of the 4 rats, the

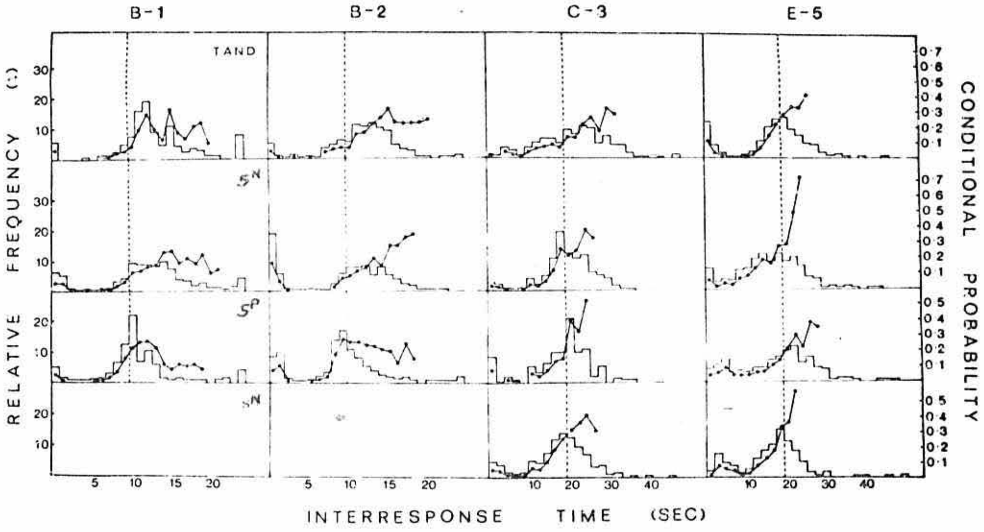


Figure 8:1

The relative frequency and conditional probability distributions of all the IRTs under each condition.

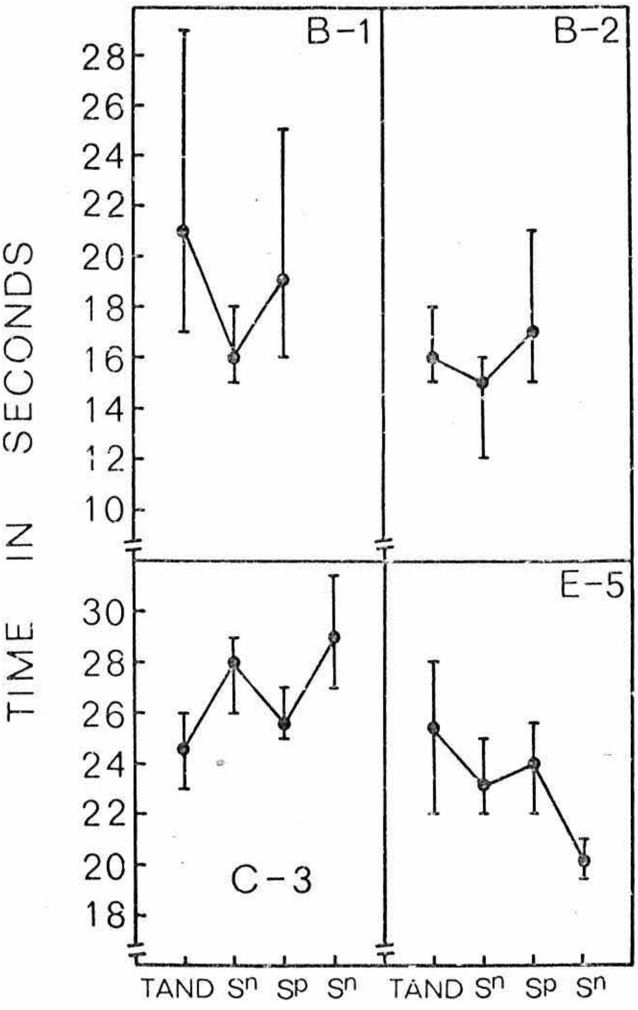


Figure 8:2

The median value, and interquartile range, of the duration of the postreinforcement pause under each condition.

postreinforcement pause duration was lower under the S^N than under either the S^P or the tandem condition, and this effect was reversible for E-5 when changing back to the S^N condition. For C-3, the postreinforcement pause was longer under S^N, and this effect also was a reversible one. There was no systematic difference between the postreinforcement pause under the tandem and S^P conditions.

Considering the distribution of responses following the completion of a non-reinforced component (Fig. 8:3), there was a shift to the left in the modal IRT, and a steepening of the gradient of the distribution, as the conditions were changed from tandem to S^N to S^P. This effect was not evident for E-5, but on transition from S^N to S^P the modal IRT changed from 18 sec to 20 sec. E-5 did not show any effect of changing back to S^N, but C-3 showed a spreading of the distribution.

Figure 8:4 shows the distribution of responses following an error. B-1 showed a marked sharpening of the distribution as the conditions were changed

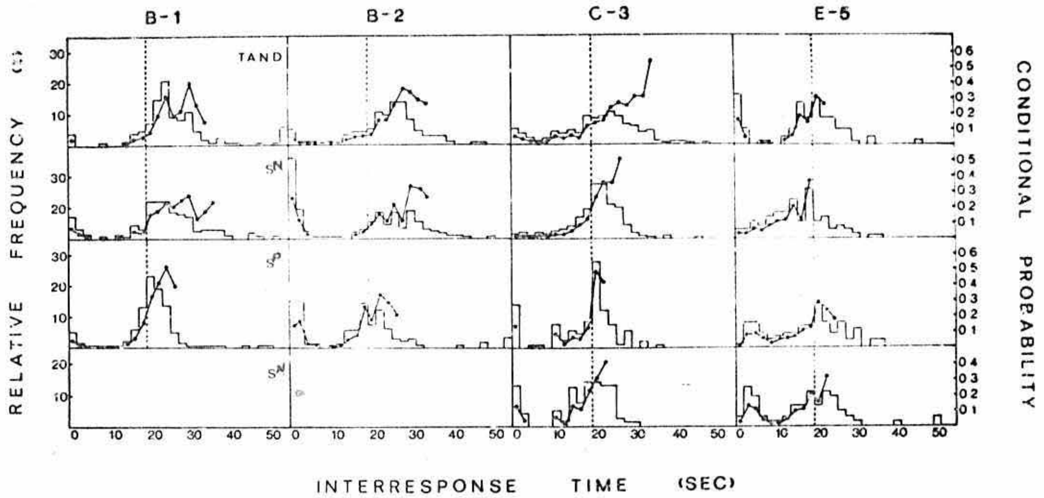


Figure 8:3

The relative frequency and conditional probability distributions of the IRTs following the completion of a non-reinforced (drl) component.

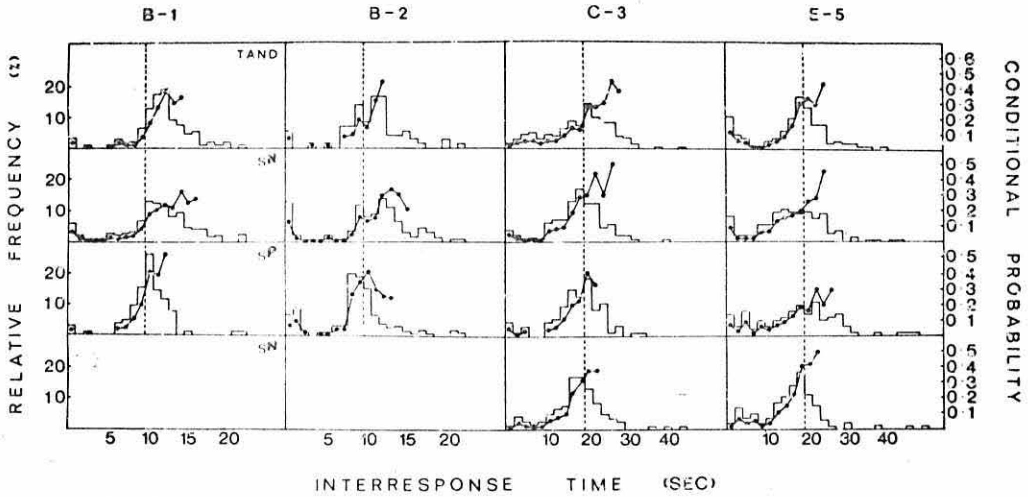


Figure 8:4

The relative frequency and conditional probability distributions of the IRTs following an error.

from tandem to S^N to S^P, whereas this effect occurred for B-2 only on transition from S^N to S^P - there was no discernable difference here between the tandem and S^N conditions. Subject E-5 showed a greater spread of IRTs on transition from tandem to S^N, and a change to S^P shifted the peak to the right, and sharpened it. On changing back to S^N, the peak moved slightly to the left but sharpened even more. The behaviour of C-3 following an error was unaffected by the stimulus changes, although the distribution was least sharp under the tandem condition.

The rate measures shown in Fig. 8:5 were somewhat equivocal. For B-1 and C-3, the overall response rate increased as the conditions were changed. For B-2, the lowest response rate occurred under the S^N condition, whereas there was no effect at all on the rate of responding of E-5 of changing the stimulus conditions. The component rate remained constant over the conditions for B-1, and was highest under S^N for B-2. For C-3 there was no effect on component rate until the transition from S^P to S^N, when it decreased. The

see Erratum (iii)

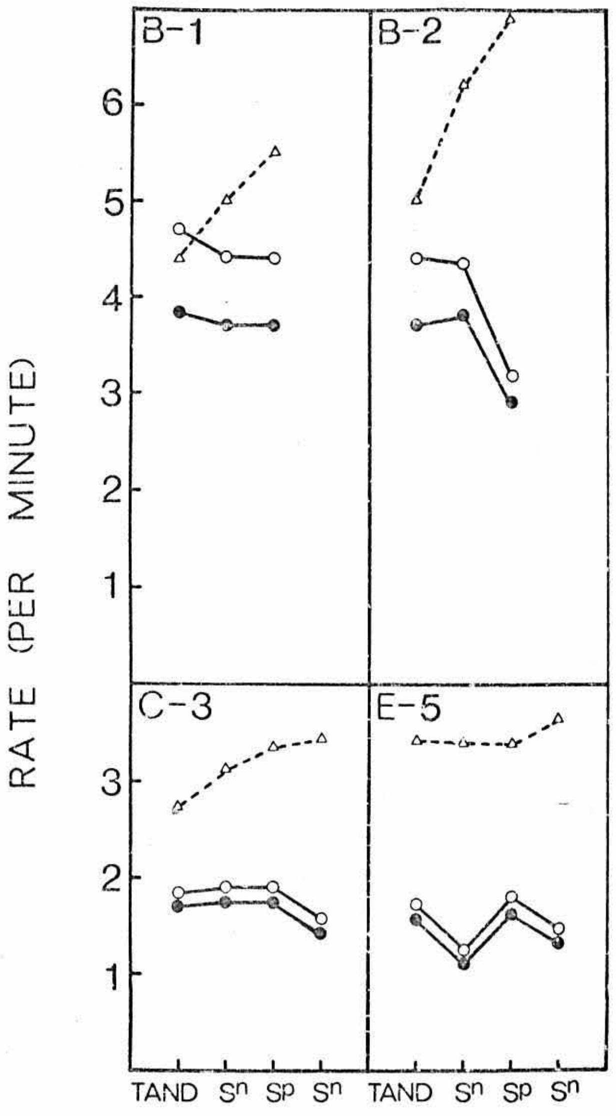


Figure 8:5

The rate measures. The triangles represent the overall rate of lever-pressing; the closed circles represent the overall rate of emission of (drl) components; the open circles represent the running rate of (drl) components.

component rate of E-5 decreased from tandem to S^N, increased on changing to S^P, then decreased on transition to S^N.

The running rate of components decreased with changes in condition for both B-1 and B-2. It increased slightly on changing from tandem to S^N in the case of C-3, was unchanged in S^P, then decreased slightly on changing back to S^N. The running rate of components mirrored the changes in overall component rate for E-5, with a decrease on changing from tandem to S^N, then an increase at S^P, and finally a decrease on changing back to S^N.

Less equivocal, however, were the functions relating the mean duration of each component within the interreinforcement interval as a function of the stimulus conditions. Figure 8:6 shows that in 3 out of 4 cases, after the first 3 components, the tandem function was higher than the S^N function, which was higher than the S^P function. After the tenth component, there was a tendency for the functions to come closer together, occasionally crossing. In the case of E-5, however, there was such variability that no systematic differences were

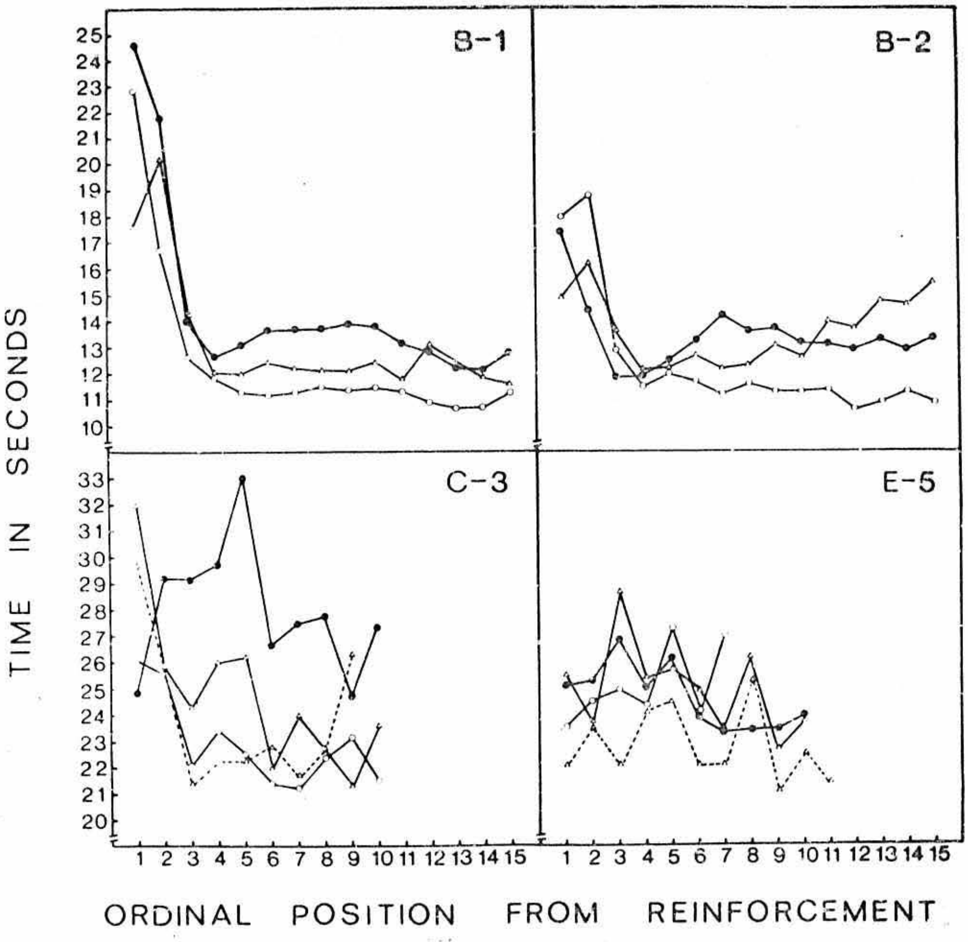


Figure 8:6

The mean duration of each IRT satisfying each (drl) component within the inter-reinforcement interval. The closed circles represent the tandem condition; the open circles represent the S^P condition; the triangles connected by solid lines represent the first S^N condition; the triangles connected by dashed lines represent the second S^N condition.

observed. On transition from S^P to S^N, however, the function was at its lowest and did not revert to its previous S^N level.

DISCUSSION

From the data presented in the Results section, the exact effect of the brief stimulus procedures appear to be equivocal, since any very positive effects (such as on postreinforcement pause and mean component duration) apply to only 3 out of the 4 rats, and other measures (such as the rates) vary unsystematically. There is, however, one very important point to be considered in relation, not only to this experiment, but to all the experiments presented in this Section, and that is that there is within-component patterning under all conditions, and one is trying really to assess any differences in patterning between conditions. In second-order schedule literature, the brief stimulus is considered to be effective if it engenders "typical component behaviour" when compared with the tandem condition, which is held to be one in which there is no patterning (cf. Marr, 1969; Malagodi et al. 1973; Stubbs, 1971). In the present experiment, patterning appropriate to the (drl) contingency was evident even in the tandem condition. This makes a comparison of the present experiment with other second-order schedules difficult.

It might be argued in the present context that the effect of adding S^N to the tandem condition was to 'improve' the component behaviour, and that there was a further 'improvement' on pairing the stimulus with reinforcement. This is borne out in part by the overall distribution of IRTs (Fig. 8:1), and by the decrease in mean component duration, for 3 animals, within the interreinforcement interval (Fig. 8:6). The frequency distribution, however, shows no discernable difference between the tandem and S^N conditions, but a sharpening on changing to S^P. This might be interpreted as evidence in favour of the traditional view that there is an effect only when the brief stimulus is paired with reinforcement (cf. Kelleher, 1966 b; Malagodi et al. 1973; Marr, 1969). The function showing a decrease in mean component duration (Fig. 8:6), however, might be interpreted as evidence for the proposition that S^N has more effect than no stimulus, but less effect than S^P.

A more detailed analysis of behaviour is available, however, since there were 3 discrete events initiating behaviour. One was reinforcement, and for 3 of the 4 rats the postreinforcement pause was shortest under the S^N condition, there being no systematic difference between the tandem and S^P conditions. For the remaining subject, the pause was longer in the S^N condition than in the tandem or S^P conditions. de Lorge (1971) observed a very clear effect on postreinforcement pause duration of manipulating stimulus conditions on a multiple schedule with FR(VI) components, the second-order schedule components terminated by either S^P or S^N (in one experiment), and S^P and no stimulus (in the other experiment). He found that the S^N condition engendered longer postreinforcement pauses than did the S^P condition (an effect observed for only one rat in the present study), and that the longest postreinforcement pause occurred in the tandem condition. Both Findley and Brady (1965), and Thomas and Stubbs (1966) obtained similar effects, although they did not include the S^N condition. The most obvious difference between the present study and these experiments is that they all utilised overall FR schedules, whereas a RR schedule was used here.

Further discussion of this point, then, will be deferred to Chapter 9 where overall FR schedules were used.

Figure 8:3, which is the distribution of IRTs following a non-reinforced component, shows differences between the stimulus conditions in the form of a sharpening or improvement in component behaviour. These distributions are interesting because, intuitively, they might show systematic differences since they show what the animal does after he makes a 'correct' response and receives nothing, S^N, or S^P. There was evident here much less of an effect between the tandem and S^N conditions than between the S^N and S^P conditions for all subjects, but notably for rat E-5.

The IRTs following an error, however, (Fig. 8:4) show less of a difference between the stimulus conditions, although one is still evident on transition from S^N to S^P for the two rats with (drl 10-sec) components. This equivocal effect is, perhaps, what one might expect, since under all conditions an error has the same consequence - it resets the component timing clock.

A within-subject analysis is possible, taking Figs. 8:3 and 8:4 together. How does behaviour following an error compare with that following a correct response? For 3 of the animals, under the tandem condition there was more accurate (drl) behaviour following an error than following a correct response, while for the remaining subject (E-5), there was no difference. Both of the rats with (drl 20-sec) components emitted more accurate behaviour after S^N than after an error, B-1 showed no difference, while B-2 was more accurate after an error than after S^N. The same effects held for each animal on comparing the behaviour following S^P and following an error.

This latter point, that S^N and S^P behaved the same way for each animal, is important because it suggests that the stimuli have similar functions, but the differences between the S^N and S^P conditions discussed above suggest differing degrees of effect.

A point of general interest is that the component behaviour has been said to be "accurate", "sharpened", "patterned", etc., and it could be argued that these terms have little use in a scientific thesis. What is meant by these terms here is simply a change in the distribution of IRTs towards the distribution demanded by the schedule conditions. In the terminology of Catania (1973 a) what is meant is a change towards the descriptive operant (cf. Section I and II). There is, however, a further problem. There remains an element of subjectivity since there is no accurate quantitative measure to describe the bi-modal distributions obtained under DRL schedules. This point is discussed further at the end of Section III.

Several authors have reported higher overall response rates under S^P as compared with S^N conditions (cf. Byrd and Marr, 1969; de Lorge, 1969; Kelleher, 1966 b; Malagodi et al. 1973) and that brief stimulus procedures maintain higher rates than comparable tandem schedules (cf. de Lorge, 1967, 1969, 1971; Marr, 1969; Stubbs, 1969; Thomas and Stubbs, 1966, 1967). Two of the rats in the present experiment (B-1 and C-3) showed both of these effects (Fig. 8:6). Other workers have reported lower rates under brief stimulus than under tandem conditions (cf. Byrd and Marr, 1969; Stubbs, 1971). Subjects B-2 and E-5 showed these effects. The lesson to be drawn from these anomolies is simply that rate measures do not seem to be a useful dependent variable in this type of situation. Even the component running rates, which proved useful in Sections I and II showed equivocal results. One must agree with Stubbs (1971) that

> "the lack of consistent findings across past experiments and within the present series of experiments raises some questions concerning the utility of...rate measures" (p.310).

Both of the rats with (drl 20-sec) components experienced a reversal to S^N after the S^P condition. Examination of the overall distribution of IRTs suggests a reversal of the effect, but examination of the component duration functions show no reversal with the lowest function occurring in the second S^N condition. The postreinforcement pause effect, although different for each subject, was reversible. It is clear, then, that some dependent variables show that the behaviour controlled by S^N is retrievable, whereas others show that it is not. This latter irreversibility has been termed "metastability" by Staddon (1965), and has been reported in a second-order schedule situation by Stubbs and Cohen (1972).

In conclusion, there has been obtained a change in component behaviour towards that normally engendered by the component schedule as the brief stimulus conditions have been changed. The functional and descriptive operants were most similar under the S^P condition. There often appeared to be little difference between the tandem and S^N conditions, but the degree of difference depended largely on the dependent variable examined. For each subject, the different effects of the brief stimuli were seen clearly when the behaviour following a correct IRT was examined. It also was the case that any difference on changing from S^N to S^P was at least partly reversible, but here again choice of dependent variables was important.

A tentative conclusion of the present report is that statements about the absolute effects of brief stimulus manipulations on second-order schedules are not possible. It seems reasonable to expect there to be degrees of stimulus effects, depending on the ways in which the stimuli are programmed to occur, the nature of the component and overall schedules, the interactions between the schedules, and the particular aspect of behaviour chosen for study.

CHAPTER 9

Brief-stimulus manipulations on FR(drl)

Approximately one half of all the published studies of second-order schedules have used overall FR schedules, and these include the only reported experiments with (drl) components. Not all of these studies have compared the effectiveness of S^N versus S^P conditions, although some have, so the experiment reported in this Chapter may be more comparable with other second-order schedules than was the experiment reported in Chapter 8.

METHOD

Subjects

Four albino rats served, each having been subjects on the experiment reported in Chapter 3. None of the subjects had previously been exposed to the brief stimuli. All were maintained at approximately 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage. At the start of the experiment, each of the rats was 230 ± 20 days old.

Apparatus

The standard experimental chamber was used. The brief stimuli were 0.75 sec in duration, 100 Hz frequency, and 80 ± 2 db intensity. To a human observer, this tone was clearly audible above the noise (60 ± 2 db) of an exhaust fan.

Procedure

There were few procedural differences from the experiment reported in the previous Chapter. Sessions lasted for 1 hour, and were run 6 days each week. The number of hours under each condition is shown in Table 9:1.

After a minimum of 20 sessions under the tandem condition, and when behaviour was stable, S^N was introduced. In the next phase, S^P was introduced, and then finally S^N was re-introduced. At the end of the experiment, each animal was put onto the appropriate simple DRL schedule for a few sessions, in order to determine the effect on DRL behaviour of the extensive experimental history.

TABLE 9:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
E-1	FR6(drl 10-sec)	92
	FR6(drl 10-sec: S^N)	31
	FR6(drl 10-sec: S^P)	32
	FR6(drl 10-sec: S^N)	24
E-2	FR6(drl 10-sec)	97
	FR6(drl 10-sec: S^N)	25
	FR6(drl 10-sec: S^P)	30
	FR6(drl 10-sec: S^N)	25
E-3	FR6(drl 20-sec)	43
	FR6(drl 20-sec: S^N)	29
	FR6(drl 20-sec: S^P)	54
	FR6(drl 20-sec: S^N)	29
E-4	FR6(drl 20-sec)	29
	FR6(drl 20-sec: S^N)	32
	FR6(drl 20-sec: S^P)	28
	FR6(drl 20-sec: S^N)	26

RESULTS

Figure 9:1 shows the frequency distribution, and the distribution of the conditional probabilities of IRTs. In the case of the rats with (drl 10-sec) components, there was little effect on changing to S^N from the tandem condition, although the distribution sharpened for the other 2 rats. For 2 of the 4 subjects (E-1 and E-4), changing from S^N to S^P improved the behaviour, although the distribution was spread for E-3, and there was no effect for E-2. On reversal to S^N, E-1 and E-2 showed no change, E-3 showed a sharpening similar to that obtained under the previous S^N condition, and the distribution for E-4 spread towards the shape of the distribution under the previous S^N condition.

Figures 9:2, 9:3, and 9:4 show more detailed analysis of this data. Figure 9:2 shows the behaviour initiated by the reinforcing stimulus - the postreinforcement pause. Its duration decreased on changing from tandem to S^N for E-1 and E-3, yet increased for E-2 and E-4. Three animals showed an increase in pause on changing to S^P, while E-2 showed

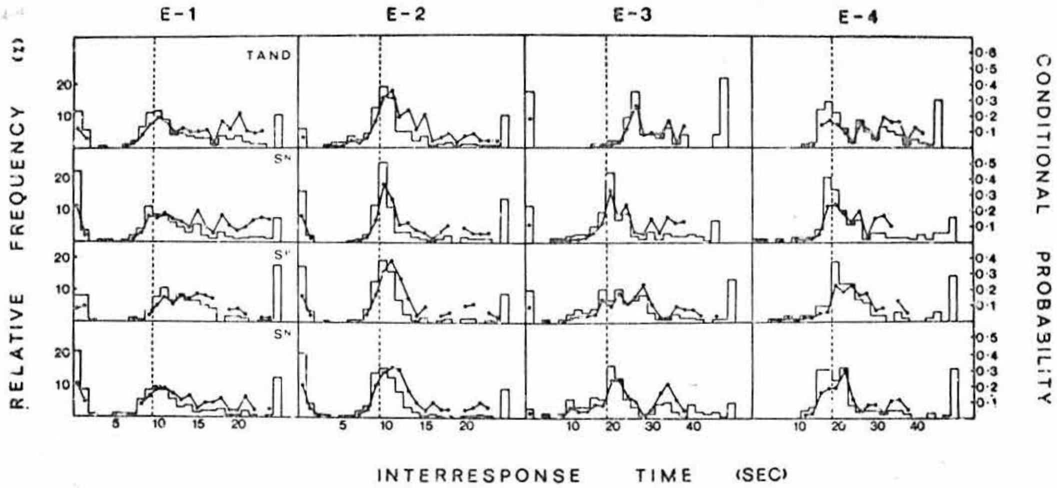


Figure 9:1

The relative frequency and conditional probability distributions of all the IRTs under each condition.

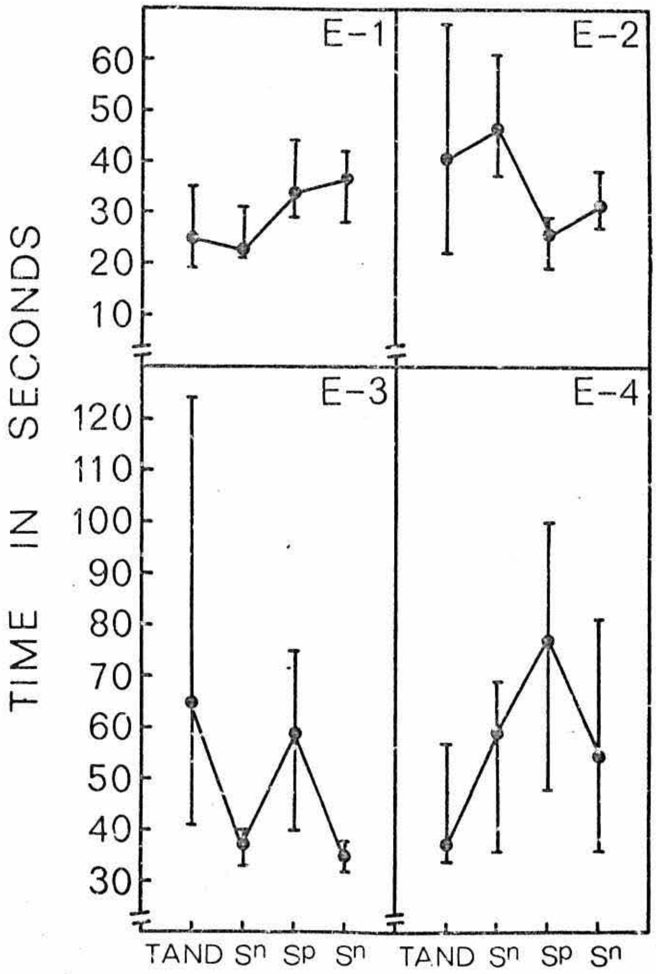


Figure 9:2

The median value, and interquartile range, of the duration of the post-reinforcement pause under each condition.

a decrease. On reversal to S^N, 3 rats reversed the direction of change from S^N to S^P. The fourth subject (E-1) showed a further increase.

The distribution of behaviour following a correct IRT is shown in Fig. 9:3. For E-1, there was no systematic difference between any of the conditions. For the remaining 3 subjects, however, there was a considerable sharpening of the distribution on changing from tandem to S^N. In the case of E-2 and E-3, the effect of changing to S^P was to spread the distribution out, although the same change sharpened the behaviour of E-4. Two subjects (E-3 and E-4) showed a reversal to the behaviour under the first S^N condition, but E-2 showed a further spreading of the distribution.

Figure 9:4 shows the behaviour following an error. In this case, both E-1 and E-2 showed no difference between any of the stimulus conditions. E-3 considerably improved his behaviour when S^N was introduced, whereas E-4 showed little difference. When the stimulus was paired with reinforcement, the distribution for both E-3 and E-4 spread slightly to the right, an effect which was reversed on changing back to S^N for E-3.

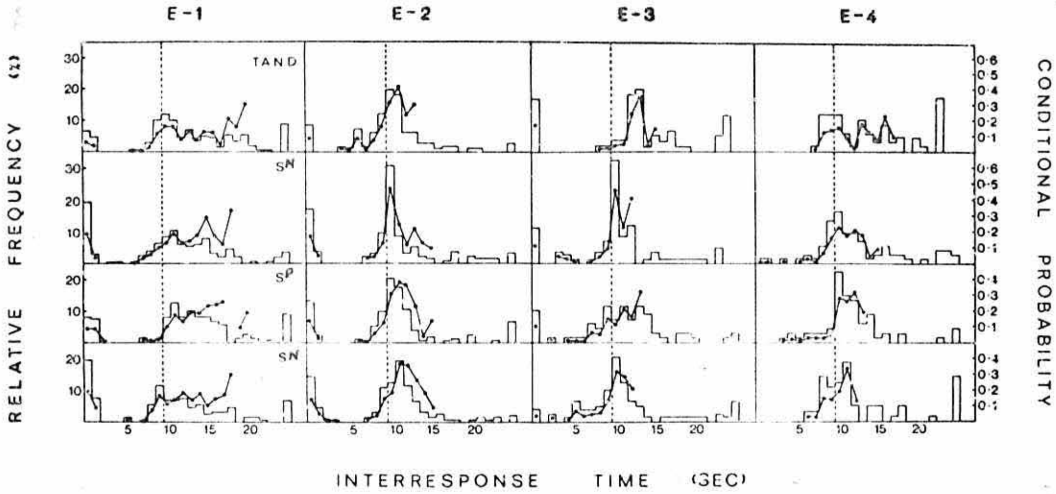


Figure 9:3

The relative frequency and conditional probability distributions of the IRTs following the completion of a non-reinforced (drl) component.

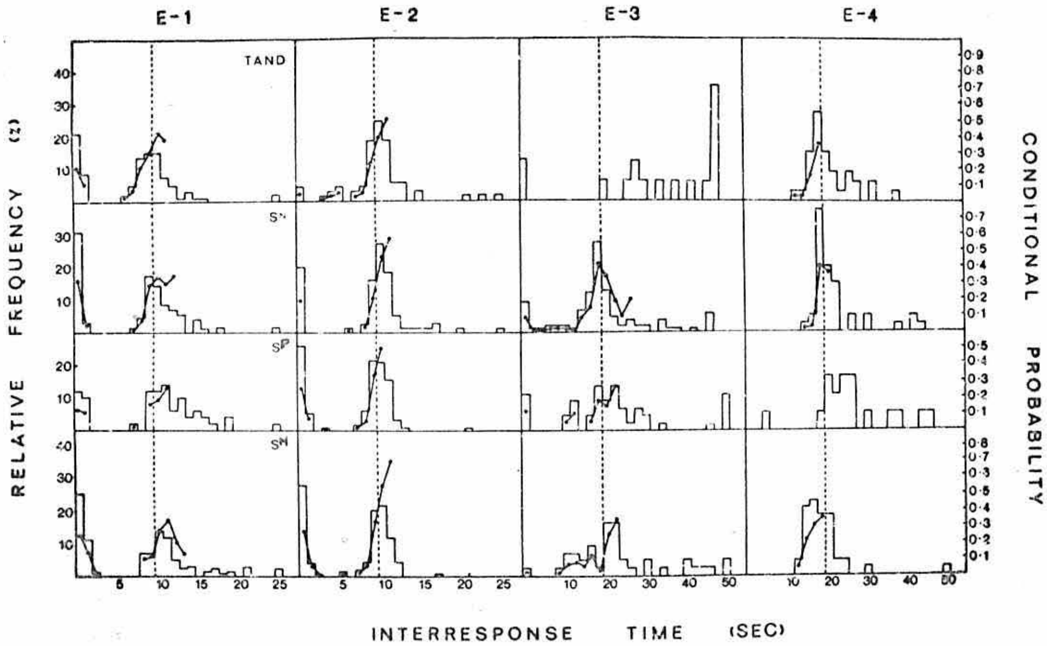


Figure 9:4

The relative frequency and conditional probability distributions of the IRTs following an error.

Rate measures are shown in Fig. 9:5. The overall rate of lever pressing showed the same pattern for 3 of the 4 rats, being higher in both of the S^N conditions than the S^P condition, and increasing on changing initially from tandem to S^N. For the remaining rat (E-2), this pattern was reversed, except there was no effect of reverting to S^N from S^P. The component rate increased for all subjects on introduction of S^N, and decreased for 3 subjects on being paired with reinforcement. In the case of E-2, this manipulation increased the component rate. On reversal to S^N, the direction of change was reversed for E-2 and E-3, but there was a further decrease in the case of E-1, and no change for E-4. The running rate of components also increased for all subjects on changing from tandem to S^N, but was less systematic in the other changes. It increased for E-1, decreased for E-2 and E-3, and remained unchanged for E-4 on the addition of S^P. The effect of changing back to S^N was as equivocal, with a decrease for E-1 and E-4, but no change for the other 2 rats.

The mean duration of each component as a function of its position within the interreinforcement interval is shown in Fig. 9:6. For both of the

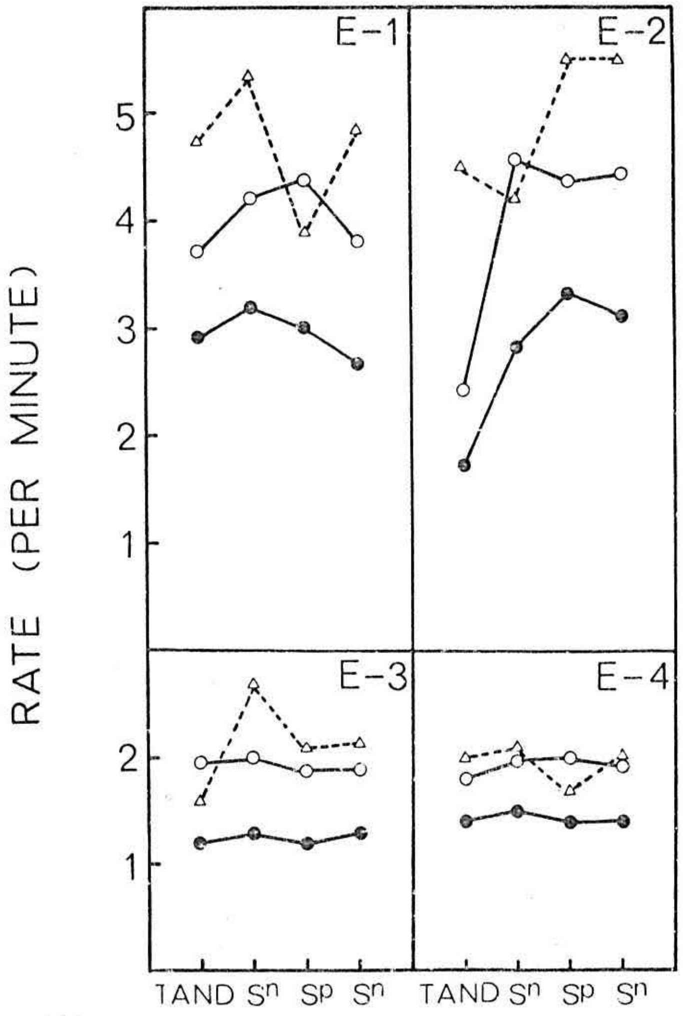


Figure 9:5

The rate measures. The triangles represent the overall rate of lever-pressing; the closed circles represent the overall rate of emission of (drl) components; the open circles represent the running rate of (drl) components.

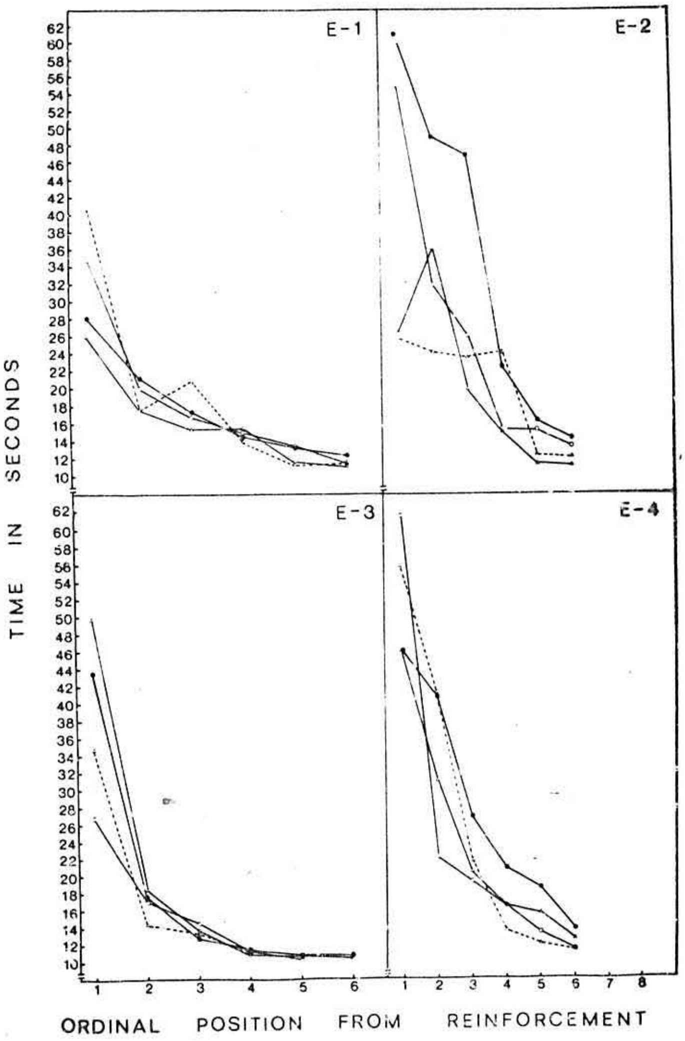


Figure 9:6

The mean duration of each IRT satisfying each (drl) component within the inter-reinforcement interval. The closed circles represent the tandem condition; the open circles represent the S^P condition; the triangles connected by solid lines represent the first S^N condition; the triangles connected by dashed lines represent the second S^N condition.

subjects with (drl 10-sec) components, there was no systematic effect, and the only noticeable effect for E-3 and E-4 was that the tandem condition engendered higher mean durations than did the brief stimulus conditions. The typical pattern of decreasing duration was also evident.

DISCUSSION

A lack of complete generality in some of the measures is an obvious conclusion here, although several dependant variables showed the same effect for 3 out of 4 animals. As in the previous chapter, the most general statement that may be made is that there was a tendency to improve the behaviour on adding S^N, while S^P improved the behaviour even more. This is evident from the overall IRT distribution (Fig. 9:1), and the distribution of behaviour following a completed (drl) component (Fig. 9:3). There were, however, exceptions to this effect, where the behaviour occasionally deteriorated slightly on addition of the brief stimuli. It is clear however, that this latter type of instance was relatively infrequent.

de Lorge (1971) reinforced VI components under an overall FR schedule and reported that the postreinforcement pause duration was longest under the tandem condition, and longer under the S^N than under the S^P condition. In the present experiment, 2 subjects paused longer under the tandem than under the S^N condition, while 2 paused longer under the tandem schedule. Three rats increased the duration of their pauses on changing to S^P, while the remaining rat decreased the duration of his pause. These findings are not in agreement with those of de Lorge (1971), so it seems clear that brief stimulus effects cannot be determined solely by the overall schedule. Differences between the present experiment and de Lorge's (1971) study include:

(i) different species (rats as opposed to pigeons)
(ii) different brief stimuli (de Lorge used keylights)
(iii) different methods of comparing brief stimuli (de Lorge used a multiple schedule)

It seems unlikely that there will emerge an absolute brief stimulus effect, divorced from considerations of schedule interactions, species differences, brief stimulus type etc.

Stubbs (1971) made the point that overall rate measures have proved to be equivocal in analyses of second-order schedules, an impression which has had further validation in this thesis. However, overall rate measures in the present schedule showed surprising uniformity, being highest in both of the S^N conditions for 3 of the 4 animals. The overall component rate showed a more general effect of increasing on addition of S^N and decreasing on pairing the stimulus with reinforcement (for 3 subjects). This finding, however, is not comparable with any other findings in the literature, because this measure is seldom used. The running rate of components also increased on changing from the tandem condition to S^N, but was not systematically affected by other changes.

It is unfortunate that any effects on component rate should be uncorroborated. There are two reasons for this. Firstly, if the component is to be treated as a unitary response, then the component rate is analogous to response rate under the simple schedule, and may be expected to be as useful as response rate. Secondly, changes in the number of components may reflect changes in the control of the overall schedule brought about by changes not related to the parameters of the overall schedule. This latter point is another facet of the arguments presented in Section I for an analysis of the interactions between overall and component schedules in second-order schedules.

A comparison of Figs. 9:3 and 9:4 shows the difference in behaviour under each stimulus condition following a correct response and an error. Under the tandem condition, when there was no difference in stimulus presentation following a completed component and an error, for 3 of the rats the behaviour was better following a mistake, whereas for E-3 there was no noticeable difference. When S^N followed a correct response, E-1 and E-4 still showed better discrimination following a mistake than following a stimulus, while there was no difference for the other rats. In all cases, there was no difference in the responding preceded by an error and that preceded by S^P. E-1 and E-2 discriminated more accurately following an error under the second S^N condition, whereas there was little change for E-3 and E-4.

These results are particularly interesting since, although there were differences in the behaviours initiated by correct and incorrect responses <u>between</u> stimulus conditions, <u>within</u> any particular condition an error generally led to more accurate behaviour than did S^N, and led to the same behaviour as that initiated by S^P. There were no occasions when a brief stimulus led to more differentiated responding than that initiated by an error, which could indicate that lack of feedback may be as useful to the animal as positive feedback. That this was not the case is demonstrated by the finding that the behaviour was still better following a mistake under the tandem condition (for 3 subjects), when there was no feedback, even for a correct response. This finding is discussed at greater length at the end of this Section.

There was little systematic effect of brief stimulus manipulations on the mean duration of each component as a function of its position within the interreinforcement interval. There are two possible explanations for this. One is that the temporal control exerted by the FR schedule - (shown by a systematic decrease in component duration throughout the interreinforcement interval) - is so strong that it masks any other effect. There is also the possibility that any effects are not of the kind that would show in a measure such as the mean duration of a component. The effects on the IRT distributions have been small, and these effects could easily be 'lost' in the averaging process.

As in the previous experiment, a tentative conclusion may be reached. It seems to have been the case that S^N controlled more accurate behaviour than did the tandem condition, and S^P controlled more accurate behaviour than did S^N. The finer analyses showed very interesting relationships between the errors and correct responses, and these are discussed at greater length at the end of this Section.

CHAPTER 10

Brief-stimulus manipulations on FI(drl)

The baseline tandem schedule used here was obtained in the experiment reported in Chapter 6. It was shown that there were many ways in which the component was similar to the lever press in simple FI schedules. The purpose of the experiment reported here was to assess the effect on this behaviour of manipulating the brief-stimulus conditions.

METHOD

Subjects

The same 3 albino rats (D-1, D-2, and C-4) and 1 hooded rat (A-1) served as in Chapter 6. At the start of this experiment, A-1 was in excess of 21 months old, C-4 was 400 ± 30 days old, and D-1 and D-2 were each 330 ± 30 days old. They were maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage.

Apparatus

The standard experimental chamber was used. The brief stimuli were 0.75 sec in duration, 100 Hz frequency, and 85 ± 2 db intensity. This tone was clearly audible to a human observer above the noise (60 ± 2 db) of an exhaust fan.

Procedure

There were no differences from the procedure used in the previous two Chapters. The minimum number of sessions acceptable before changing conditions was 20. The sessions were generally 1 hour in duration and were run six days each week. The number of hours under each condition is shown in Table 10:1.

TABLE 10:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
A-1	FI2-min(drl 10-sec)	40
	FI2-min(drl 10-sec: S^N)	38
	FI2-min(drl 10-sec: S^P)	24
	FI2-min(drl 10-sec: S^N)	37
D-1	FI2-min(drl 10-sec)	38
	FI2-min(drl 10-sec: S^N)	39
	FI2-min(drl 10-sec: S^P)	30
	FI2-min(drl 10-sec: S^N)	29
D-2	FI2-min(drl 20-sec)	46
	FI2-min(drl 20-sec: S^N)	42
	FI2-min(drl 20-sec: S^P)	33
	FI2-min(drl 20-sec: S^N)	30
C-4	FI2-min(drl 20-sec)	52
	FI2-min(drl 20-sec: S^N)	43
	FI2-min(drl 20-sec: S^P)	20
	FI2-min(drl 20-sec: S^N)	40

RESULTS

The distribution of IRTs for each condition (Fig. 10:1) shows that there was poor temporal discrimination with respect to the (drl) contingency for D-1, even though a large number of IRTs were greater than the (drl) requirement. For the other subjects, however, typical (drl) behaviour was emitted under each condition. For A-1 and C-4, the effect of S^N was to sharpen the distribution, whereas little change was evident for D-1, and the effect for D-2 was to spread the distribution over to the right. D-1, D-2 and C-4 each showed an improvement in behaviour on addition of S^P, but this was not noticeable in the behaviour of A-1 due to an increase in the number of very long IRTs, and the subsequent decrease in the proportion of IRTs around the (drl) criterion. There was no effect of changing back to S^N for D-1 and C-4, but a slight improvement in the temporal spacing for A-1 and D-2.

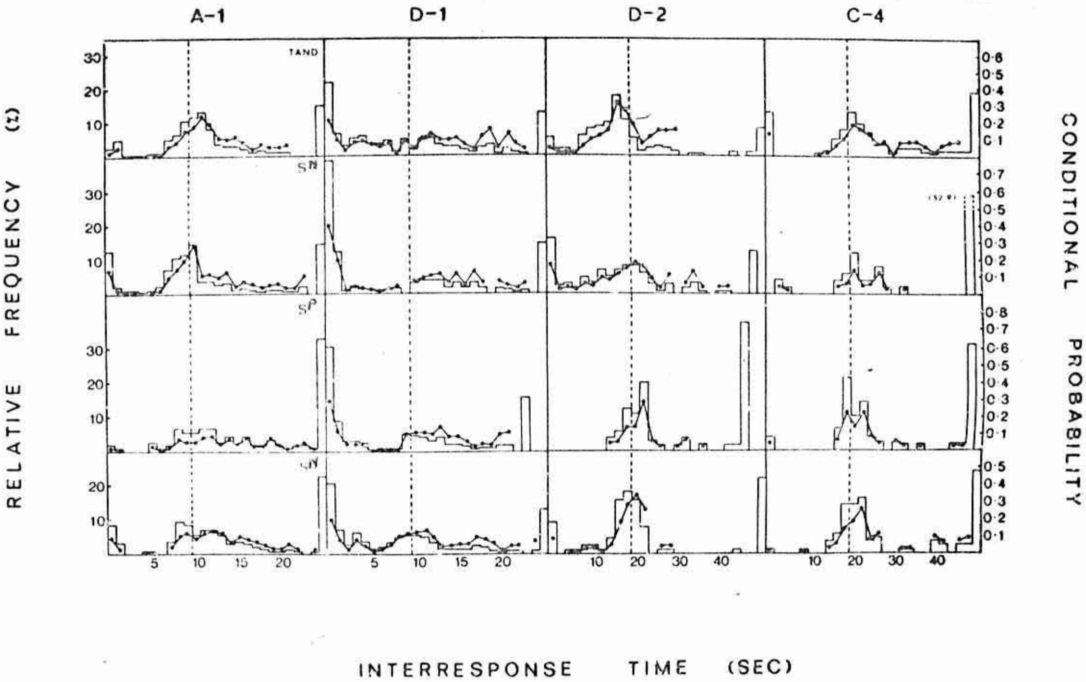


Figure 10:1

The relative frequency and conditional probability distributions of all the IRTs under each condition.

Table 10:2 shows the mean and median postreinforcement pause, with scatter, and the mean and median interreinforcement interval duration (again with scatter), for each rat under each condition. In each case there was an increase in pause on changing from the tandem to the S^N condition, but no systematic increase or decrease in interreinforcement interval. Two rats (A-1 and D-2) further increased the duration of their postreinforcement pauses on addition of S^P, but there was a decrease for the other animals. A-1 and D-1 also decreased their interreinforcement interval, but this effect is seen only in the mean data, and not in the medians. The direction of change is as unpredictable on reversal to S^N, with A-1 and D-1 showing slight increases, D-2 remaining constant, and C-4 decreasing slightly.

Less equivocal is some of the data presented in Fig. 10:2, showing the distribution of behaviour following a completed component. Three animals showed significant improvements in response spacing on the introduction of S^N, while the remaining animal (D-1) showed no effect because there was very little response differentiation evident anyway. Only

TABLE 10:2

Mean and Median Postreinforcement Pause and Interreinforcement Interval Durations
Interquartile Ranges Shown in Parentheses

		Postreinforcement Pause Duration (sec)		Interreinforcement Interval Duration (sec)	
SUBJECT	SCHEDULE	MEAN	MEDIAN	MEAN	MEDIAN
A-1	FI2-min(drl 10-sec)	59.7	61(40-74)	135	129(120-130)
	FI2-min(drl 10-sec: S^N)	75.6	80(66-93)	135	129(124-141)
	FI2-min(drl 10-sec: S^P)	80.1	84(70-99)	129	129(123-133)
	FI2-min(drl 10-sec: S^N)	86.3	85(77-98)	129	128(121-131)
D-1	FI2-min(drl 10-sec)	44.9	46(28-58)	132	129(124-137)
	FI2-min(drl 10-sec: S^N)	68.0	77(29-100)	128	128(121-130)
	FI2-min(drl 10-sec: S^P)	44.0	40(25-51)	129	127(122-135)
	FI2-min(drl 10-sec: S^N)	46.4	40(18-65)	130	127(120-130)
D-2	FI2-min(drl 20-sec)	59.4	62(29-75)	201	164(131-207)
	FI2-min(drl 20-sec: S^N)	68.6	67(36-104)	150	135(122-154)
	FI2-min(drl 20-sec: S^P)	87.8	98(64-110)	138	135(125-148)
	FI2-min(drl 20-sec: S^N)	88.1	97(53-114)	163	146(132-203)
C-4	FI2-min(drl 20-sec)	62.7	66(37-80)	138	137(127-143)
	FI2-min(drl 20-sec: S^N)	111.7	119(101-131)	137	135(127-144)
	FI2-min(drl 20-sec: S^P)	90.5	101(67-107)	141	133(123-144)
	FI2-min(drl 20-sec: S^N)	83.4	91(47-109)	138	135(125-146)

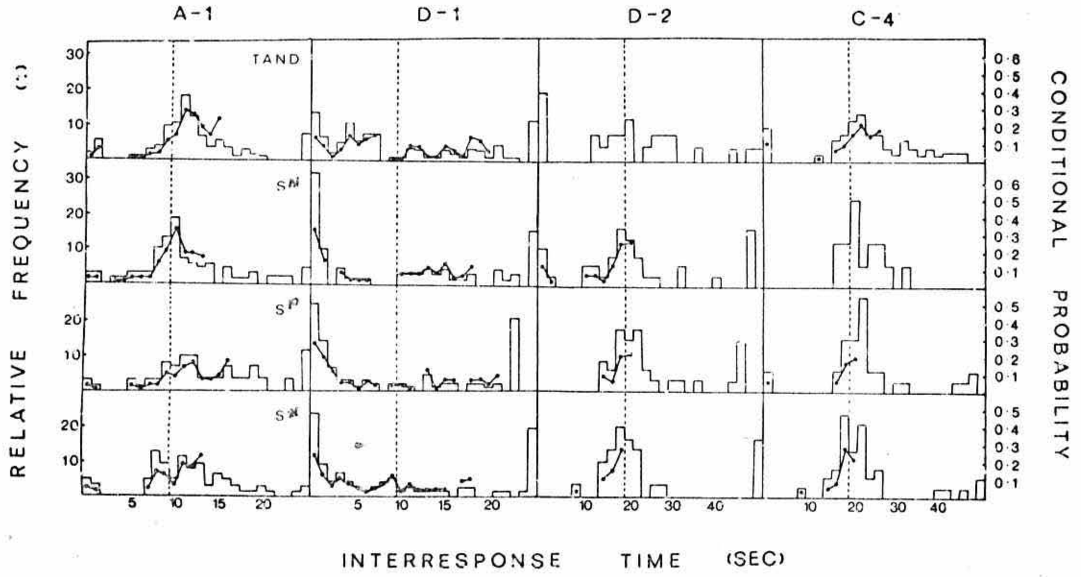


Figure 10:2

The relative frequency and conditional probability distributions of the IRTs following the completion of a non-reinforced (drl) component.

one rat (A-1) showed a change on adding S^P, and that consisted of a deterioration in patterning. On reverting to S^N, this animal's behaviour improved slightly, but did not regain the same degree of differentiation present under the first S^N condition. For the other animals, there were no effects of further changing the stimulus conditions.

The behaviour following an error (Fig. 10:3), unlike that following a correct IRT, showed no change on adding S^N for any of the subjects, but was considerably improved on adding S^P. A slight reversal effect was noticed with A-1 and D-1 on changing back to S^N, but the effect was small, and was not present for the other animals.

Rate data is presented in Fig. 10:4. On changing from the tandem to S^N conditions, the overall rate of lever pressing decreased. It decreased further on addition of S^P for A-1 and D-1, but increased for D-1 and C-4. On changing back to S^N, it decreased again for A-1, D-1, and D-2, but increased for C-4. The rate of emission of components decreased between the tandem and S^N conditions for 3 rats, but increased for D-2.

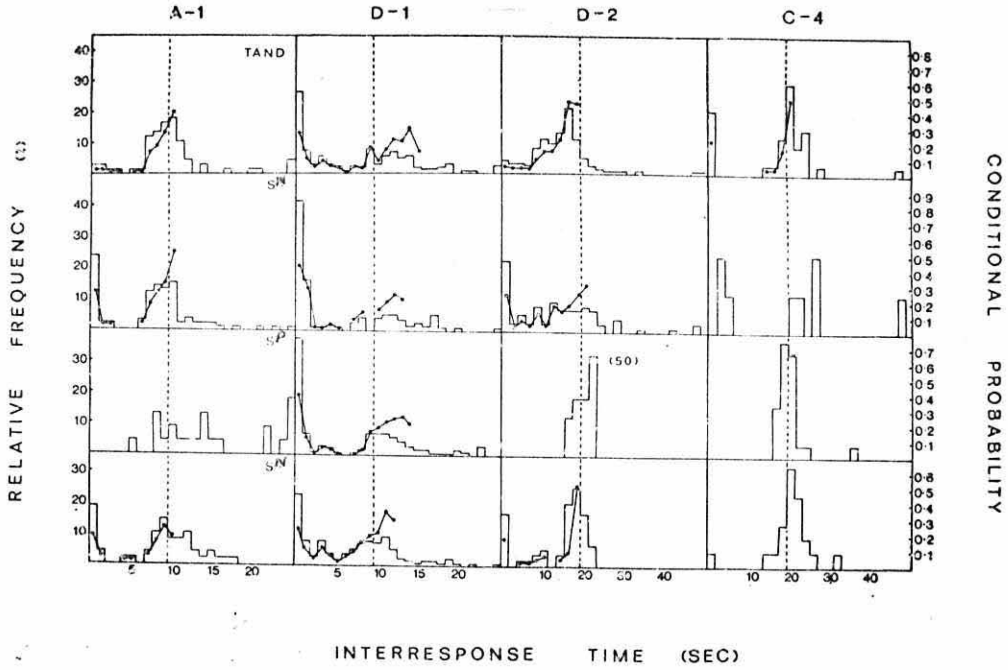


Figure 10:3

The relative frequency and conditional probability distributions of the IRTs following an error.

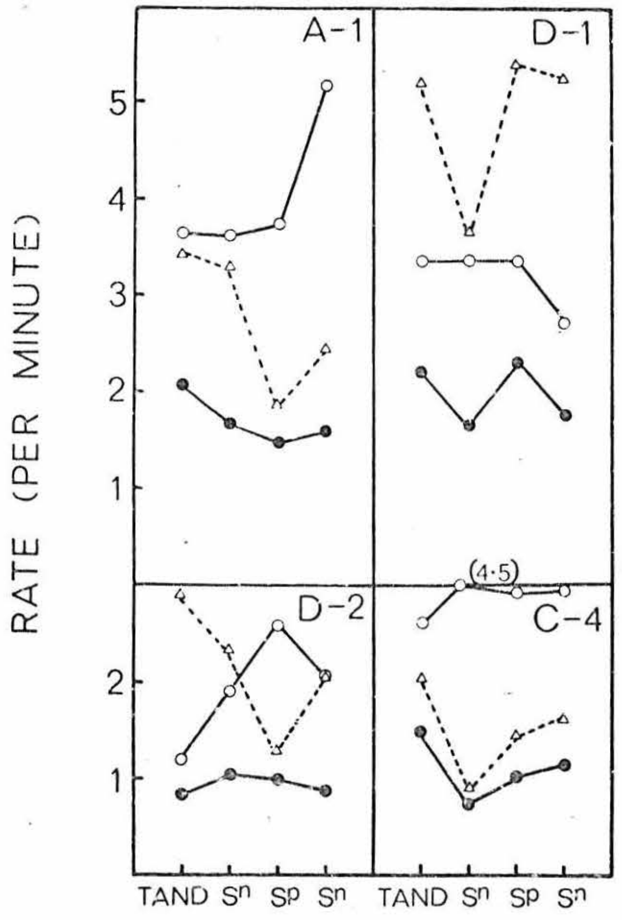


Figure 10:4

The rate measures. The triangles represent the overall rate of lever-pressing; the closed circles represent the overall rate of emission of (drl) components; the open circles represent the running rate of (drl) components.

On pairing the stimulus with reinforcement, A-1 and C-4 further decreased their component outputs, D-1 increased its output, while D-2 remained constant. Changing back to S^N had the effect of decreasing the (drl) rate of D-1 and D-2, but increased that of A-1 and C-4. Changes in the running rate of components was as unsystematic, with A-1 and D-1 showing little effect until the final S^N condition, when both exhibited a decrease, showing an increase from tand to S^N to S^P, and then a decrease, and C-4 increased to S^N, then decreased to S^P, but remained unchanged on reverting to S^N.

Figure 10:5 shows that there was no systematic effect of the stimulus manipulations on the mean duration of each component.

DISCUSSION

As suggested in Chapter 6, it seems likely that there were two conflicting sources of control over the behaviour under this schedule. The (drl) contingency requires a certain spacing of responses in time, and usually gives rise to a bi-modal distribution (cf. Harzem, 1969; Kramer and Rilling,

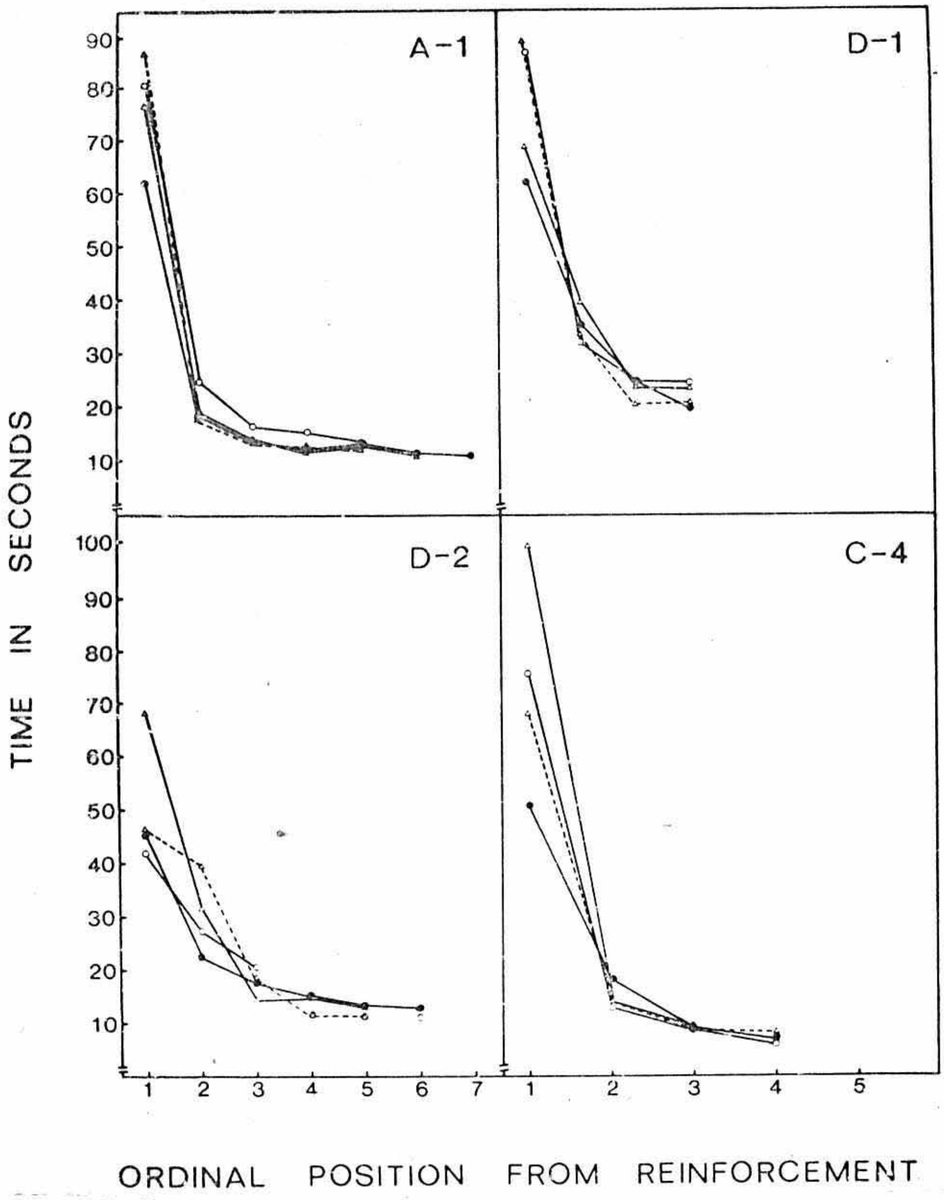


Figure 10:5

The mean duration of each IRT satisfying each (drl) component within the interreinforcement interval. The closed circles represent the tandem condition; the open circles represent the S^P condition; the triangles connected by solid lines represent the first S^N condition; the triangles connected by dashed lines represent the second S^N condition.

1970). The overall FI schedule, however, generally gives rise to long pauses following food (cf. Ferster and Skinner, 1957), and it appears that these two distinct behaviour patterns might come into conflict. In the present experiment, both patterns were evident, but there were many instances of flat, broad distributions - notably those for D-1 (Fig. 10:1) - which could result from this conflict. Consequently, it is often difficult to observe behaviour changes due to the brief stimulus manipulations for some animals under some conditions.

Where the distributions show reasonably good control by the (drl) contingency, there was a clear effect of improvement and sharpening of the behaviour on addition of S^N, and further improvements on subsequent addition of S^P (cf. Fig. 10:1). The breakdown of these distributions, however, reveal other influences.

The postreinforcement pause was not related in any simple way to the interreinforcement interval - a finding which extends the argument presented in Chapter 6 against any simple theory of responding under temporally regular schedules. The only effect observed for all animals here was an increase in pause on changing from the tandem to S^N conditions, a result contradictory to that of de Lorge (1971), indicating again that the effects of brief stimulus changes depend on a multitude of factors.

On adding S^N to the tandem schedule the behaviour following a correct IRT was noticeably improved for all subjects (cf. Fig. 10:2), but there was no change in the behaviour following an error (cf. Fig. 10:3). On the other hand, changing from S^N to S^P had no effect on behaviour initiated by a correct IRT (cf. Fig. 10:2), yet improved the behaviour following an error (cf. Fig. 10:3). Depending which aspect of the behaviour one examines, there is evidence here for the traditional view of there being an effect only of S^P and not of S^N and tandem conditions (cf. Kelleher, 1966 b; Marr, 1969), and also for the view of Stubbs (1971) that there is no difference between S^N and S^P, but no effect of tandem conditions. It is also clear, however, that an overall view of the detailed analysis of this behaviour shows that neither of these views is correct, and the situation is more complex. It seems to have been the case in the present situation that the presentation of any stimulus contingent on the completion of a component improved the behaviour following that component, whereas the behaviour following an error was affected only by the presence in the situation of a stimulus paired with food. Both of these statements are statements about the discriminative properties of correct IRTs versus errors, a general issue which is discussed at the end of Section.

Comparing the different facets of each animal's behaviour under each condition, there were two striking differences between the behaviour following a correct IRT, and that following an error. There was generally a greater preponderance of very long IRTs following a completed component, and a greater preponderance of very short IRTs following an error. This suggests, at least, that the subjects were able to discriminative between aspects of their own behaviour. That this was not due entirely to the brief stimuli is evident from the behaviour under the tandem condition (where the effect still held), but that the brief stimuli played an important part is obvious from the finding that the effect was much smaller in the tandem condition.

In general, there was much better responding with respect to the (drl) contingency after an error than after a correct response in the tandem condition.

For 3 of the 4 rats, adding S^N produced the situation where there was little noticeable difference in the behaviour following an error or a correct IRT, except for D-2 who appeared to respond more accurately after S^N. Changing to S^P again showed little difference between the two behaviours for 3 subjects, but D-1 had a better response distribution after an error, although this could easily have been due to the preponderance of long IRTs following S^P removing the opportunities for accurate (drl) responses (cf. Anger, 1956). Changing back to S^N did not affect the behaviours noticeably.

The major difference between correct responses and errors under each condition was that a correct IRT set the occasion for more very long IRTs while an error set the occasion for more very short IRTs, although both were often followed by accurate (drl) responses. Taking this together with the finding of a differential effect of S^N and S^P behaviour following correct and incorrect responses (Figs. 10:2 and 10:3), there appear to be complex interactions between the two schedules and the brief stimuli, interactions which depend on whether or not the brief stimuli are paired with food.

The effect of changing back to S^N from S^P was not generally systematic and only rarely led to behaviour similar to that under the original S^N condition. This was a general problem in these experiments and is discussed at the end of this Section.

Two other measures - the rates and the mean component durations (Figs. 10:4 and 10:5) - showed no systematic changes, with the exception of a general decrease in total behaviour output on changing from tandem to S^N. It is possible that the inadequacy of these measures was due to the strong temporal control exerted by the overall schedule. This control, as suggested in the previous Chapter, might have been so strong that the small brief stimulus effects were masked in gross measures. Overall response rates were affected by both very long (due to the FI) and very short (due to the DRL) IRTs, and were unreliable for that reason. Component rate measures also varied unsystematically, and this could have been due to an interaction between the component and overall schedule brought about by changes in the component behaviour and changes in the FI control caused by brief stimulus changes.

Evidently the factors controlling behaviour in this type of situation are more complex than has hitherto been realised, and it seems doubtful that the traditional reliance on rate measures to detect effects of this sort is justified. It was probably just such a reliance which led de Lorge (1969) to conclude that:

> "...schedules with DRL components (are) relatively insensitive to the differences between stimuli". (p.76)

CHAPTER 11

Brief-stimulus manipulations on VI(drl)

There are many ways of arranging the sequences of time intervals to form a VI schedule, and the behaviour of the subjects under VI schedules has been shown to be surprisingly sensitive to apparently small variations in the programming of these sequences (cf. Catania and Reynolds, 1968). Unless the value and sequencing of these intervals is carefully arranged, systematic changes in the probability of responding over time occur, a most notable example being a VI schedule with the intervals arranged according to an arithmetic progression (cf. Catania and Reynolds, 1968). One of the purposes of the present experiment was to compare the behaviour of rats responding under VI(drl) with the behaviour under RR(drl) (cf. Chapters 4 and 8), so a VI schedule was compiled such that the probability of reinforcement for any component remained constant over time.

One method of compiling a constant probability VI has been described by Fleshler and Hoffman (1962), and this method was used in the present experiment.

METHOD

Subjects

Four naive, male albino rats (F-1, F-2, F-3, and F-4) served, each being 150 ± 20 days old at the start of the experiment. They were maintained at 80% ad lib body weight by supplementary feeding after each session; and water was freely available at all times in the home cage.

Apparatus

The standard experimental chamber was used, with a tone of 0.75 sec duration, 100 Hz frequency, and 90 ± 2 db intensity. This was clearly audible to a human observer above the noise (60 ± 2 db) of an exhaust fan.

Procedure

Daily, 1 hour sessions were held for each subject. After lever training and continuous reinforcement for 50 reinforcements, each rat was exposed to a baseline DRL schedule; DRL 20-sec for F-1 and F-2, and DRL 10-sec for F-3 and F-4. After stability had been gained, the DRL schedule was brought under the control of a VI 2-min schedule. The next phase was to introduce S^N, and than S^P. During this condition, one rat (F-4) died. After the S^P condition, the remaining animals were re-exposed to the S^N condition, and then finally back to the original baseline schedule.

The number of sessions under each condition for each subject is shown in Table 11:1. In each case a minimum of 20 sessions were required before stability criteria could be taken.

TABLE 11:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
F-1	DRL 20-sec	72
	VI2-min(drl 20-sec)	56
	VI2-min(drl 20-sec: S^N)	43
	VI2-min(drl 20-sec: S^P)	27
	VI2-min(drl 20-sec: S^N)	27
	DRL 20-sec	66
F-2	VI2-min(drl 20-sec)	66
	VI2-min(drl 20-sec: S^N)	34
	VI2-min(drl 20-sec: S^P)	28
	VI2-min(drl 20-sec: S^N)	26
F-3	DRL 10-sec	42
	VI2-min(drl 10-sec)	56
	VI2-min(drl 10-sec: S^N)	44
	VI2-min(drl 10-sec: S^P)	27
	VI2-min(drl 10-sec: S^N)	28
F-4	DRL 10-sec	42
	VI2-min(drl 10-sec)	71
	VI2-min(drl 10-sec: S^N)	33
	VI2-min(drl 10-sec: S^P)	16*

* subject died

RESULTS

Figure 11:1 shows that the distribution and conditional probabilities of the IRTs were peaking fairly close to the required IRT under the tandem condition. On adding S^N, the distribution for F-1 shifted slightly to the right, towards longer IRTs, while the distributions of F-2 and F-3 showed little change, except for a dramatic decrease increase in the number of very short IRTs emitted by F-2. Subject F-4, however, sharpened its distribution on addition of S^N.

Erratum(iv)

Under the S^P condition, there was little change in the behaviour of F-3, although both F-1 and F-2 sharpened their distributions. F-2 again emitted a large number of bursts. No distribution is shown for the S^P condition for F-4 since this rat died after only 16 sessions under this condition, and IRT records were not at this time being taken. On reverting back to S^N, the distributions of F-1 and F-3 both shifted to the left to focus more on the

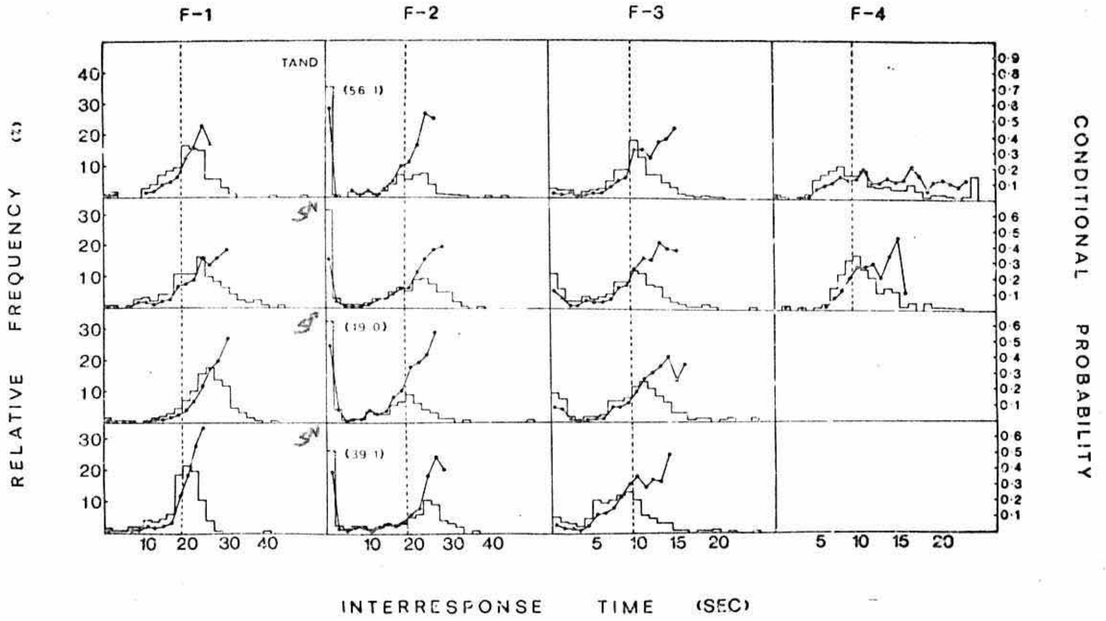


Figure 11:1

The relative frequency and conditional probability distributions of all the IRTs under each condition.

criterion IRT, but F-2 tended to emit even longer IRTs under this condition.

Three of the subjects increased the duration of their postreinforcement pauses on transition from the tandem to S^N condition, but F-3 showed a decrease (Fig. 11:2). Two of the 3 rats under the S^P condition increased their pauses above those of the S^N condition, but F-2 decreased his. These changes, however, were reversible for all subjects on changing back to S^N.

Figures 11:3 and 11:4 show the distribution of IRTs following a correct and an incorrect response respectively. Both F-1 and F-3 showed good response differentiation following a completed component under the tandem condition, and the effect on this behaviour of adding S^N was to initiate longer IRTs. The same effect was evident for F-2, who made hardly any IRTs greater than 2 sec following a correct response under the tandem condition. F-4, however, discriminated much better after S^N than after a correct response under the tandem condition. For all 3 rats, the effect on the behaviour following a correct response of

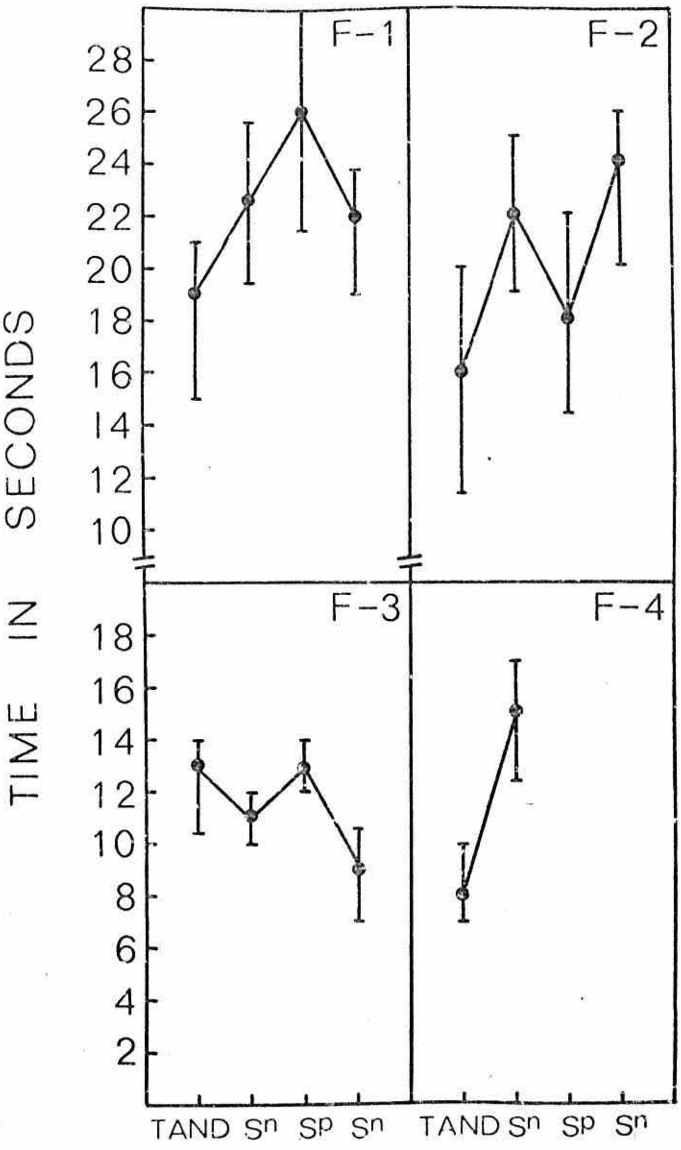


Figure 11:2

The median value, and interquartile range, of the duration of the post-reinforcement pause under each condition.

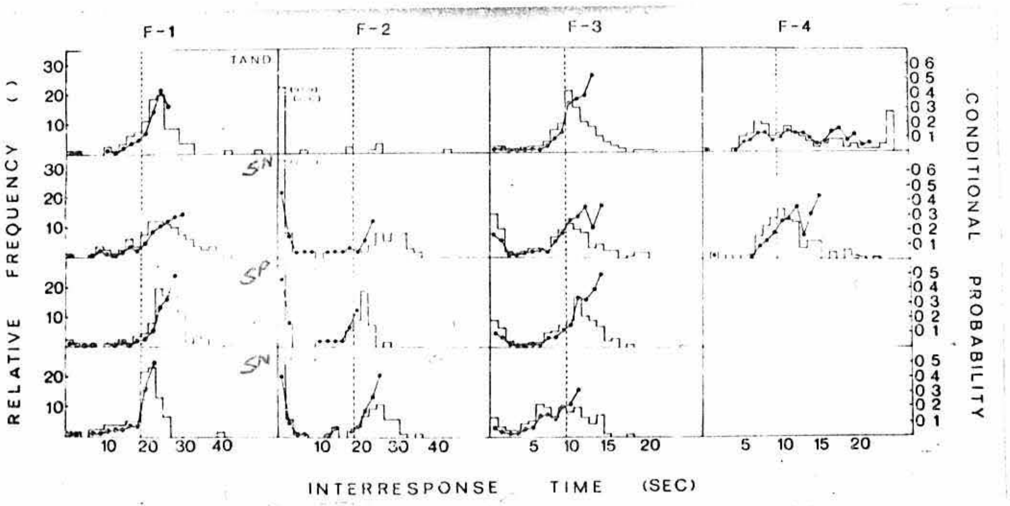


Figure 11:3

The relative frequency and conditional probability distributions of the IRTs following the completion of a non-reinforced (drl) component.

adding S^P was to sharpen the distributions, although this resulted in F-3 emitting more IRTs longer than the (drl) criterion. On reverting to S^N, the distribution improved even more for F-1, but spread out in the case of F-2 and F-3.

The direction of change of behaviour following an error was similar to the changes in the behaviour initiated by a correct response (Fig. 11:4). The most striking change was in the behaviour of F-4, who discriminated much better following an error in the S^N condition than following one made under the tandem condition. For the other subjects, the effect of introducing S^N was to spread the distribution to the right, although in the case of F-2 it is a small effect. Changing to S^P had no effect on the error-initiated behaviour of F-3, sharpened that of F-2, yet spread the distribution for F-1. Returning to the S^N condition improved dramatically the behaviour of F-1, but flattened the distribution for F-2, and shifted the distribution for F-3 to the left.

Rate measures are shown in Fig. 11:5. Subject F-2 showed very large changes in response rate, due largely to the fluctuations in the number of bursts emitted under each condition. For the other 3 animals, See Erratum(v)

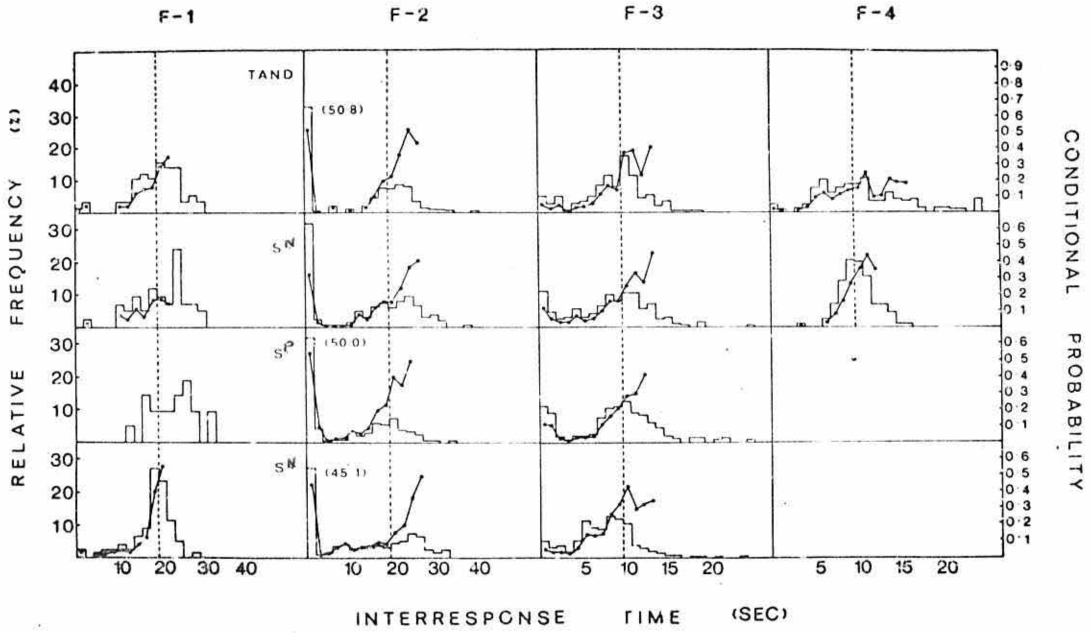


Figure 11:4

The relative frequency and conditional probability distributions of the IRTs following an error.

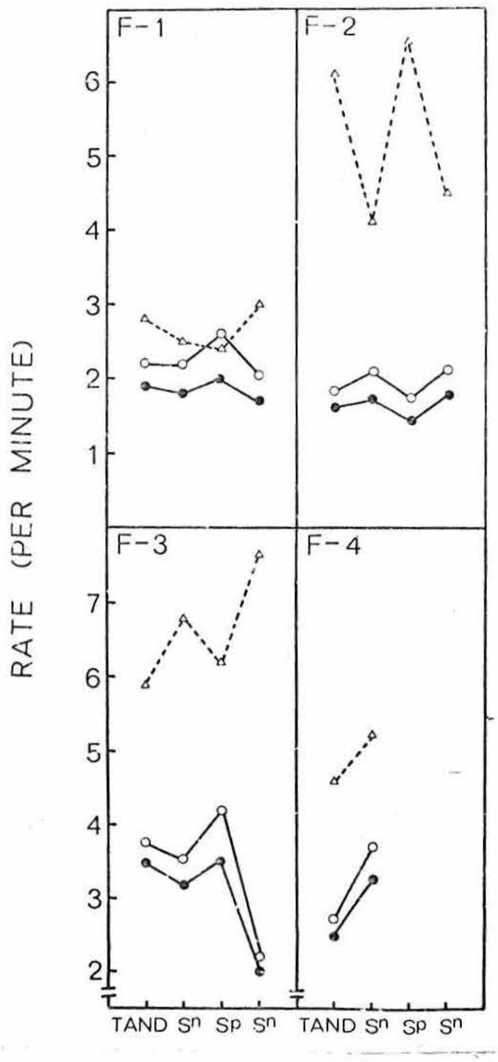


Figure 11:5

The rate measures. The triangles represent the overall rate of lever-pressing; the closed circles represent the overall rate of emission of (drl) components; the open circles represent the running rate of (drl) components.

the overall response rate increased on changing to S^N, but then varied unsystematically. The component rates and running rates also varied unsystematically - 2 animals had their highest rates under the S^P condition, while F-2 had its highest rates under both of the S^N conditions.

See Erratum (vi)

Figure 11:6 shows the mean duration of each component as a function of its ordinal position from reinforcement. There was so much variation in this measure that the functions cross each other several times. F-1, who showed the clearest differences, had the tandem function lower than the first S^N, and the S^P condition. This effect is also suggested by the graph for F-3. The second S^N function, however, for F-1, was even lower than that of the tandem condition

DISCUSSION

Of the 5 experiments presented in this Section, this is the one with the least evidence of systematic differences in the behaviour under each condition. Differences did exist, but they were generally in the

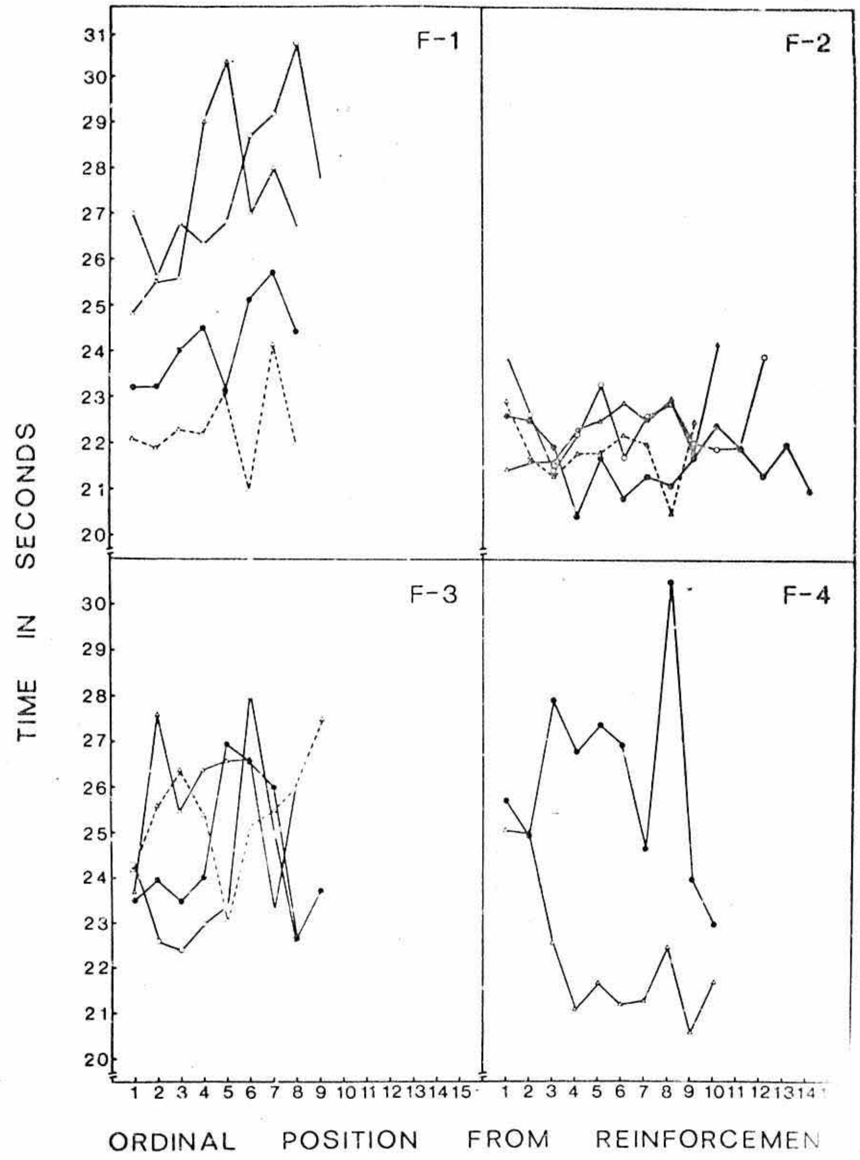


Figure 11:6

The mean duration of each IRT satisfying each (drl) component within the inter-reinforcement interval. The closed circles represent the tandem condition; the open circles represent the S^P condition; the triangles connected by solid lines represent the first S^N condition; the triangles connected by dashed lines represent the second S^N condition.

same direction for only 3 out of 4, or 2 out of 3 animals. The only universal findings were of a completely reversible effect on postreinforcement pause between the S^N and S^P conditions, and a sharpening in the distribution of behaviour following S^P after changing from S^N.

There are certain factors which are not responsible for the lack of general effects. The experimental chamber was of the standard type, and was the one used for the experiment reported in Chapter 12 - where systematic changes did occur. The intensity of the tone was such that a human observer could hear it <u>outside</u> the box, but it was not too loud since it also was used in the experiment reported in Chapter 12. Some of the previous experiments in this thesis were run for only six days each week, resulting in a break which could disrupt the behaviour. This was not the case in the present experiment since sessions were conducted each day. Table 11:1 shows that the number of sessions under each condition was quite considerable.

The explanation, then, may be sought in the schedule contingencies. The VI schedule was designed to give a constant probability of reinforcement over time, which should generate behaviour which does not change in probability of occurrence over time (cf.

Catania and Reynolds (1968)). That this was so in the present experiment may be seen by examining Fig. 11:6. The duration of each component did not vary in any systematic way with time since reinforcement, unlike the behaviour generated by FR(drl) (cf. Chapters 3 and 9) or by FI(drl) (cf. Chapters 6 and 10). Referring, then, to the descriptive system used in Sections I and II, the major effect in the present experiment must be a maintaining one. This conclusion is also reached on examination of the IRT distributions, which, in nearly all cases, show good response differentiation with respect to the (drl) requirement.

Given that the (drl) schedule exerted strong control, why was this behaviour not affected more by the brief stimulus changes? As shown in preceding Chapters, brief stimuli may effect both the overall and component schedule control, but in this case neither appears to have been systematically changed.

Stubbs and Cohen (1972) reported an experiment where they were able to increase the degree of patterning under VI(FI) by changing from S^N to S^P, but they could not reverse the effect. Cohen et al. (1973) also obtained a certain degree of irreversibility or metastability. They suggested that the reason for this might be that once a high degree of patterning has been obtained, then further manipulations cannot degrade this high level. Although this is obviously not true in a general way - there are many examples in this thesis of changes from good to bad patterning - the proposal might be rephrased thus: if a schedule engenders a high degree of patterning, then any changes brought about by stimulus manipulations will depend on the detail of the patterning. Brief stimulus effects are relative rather than absolute where there is already strong control by other aspects of the schedule.

This, however, raises more problems. A case has been made in preceding Chapters for a general effect of the improvement of component behaviour by the brief stimuli, but here the suggestion is that the precise effect of any brief stimulus depends largely on the exact patterning of the existing behaviour. These are not incompatible formulations, but operate on different levels. The former is rather gross and is useful only where the schedule conditions allow wide variability. The latter is on a more molecular level, and applies when the schedule conditions allow much less variability. It will be argued at the end of this Section that the study of complex schedules should be aiming towards this latter type of theory. The dependant variables and experimental conditions of the present experiment do not provide sufficient data for this type of theory.

Comparing the behaviour initiated by an error with that initiated by a correct response, often no difference was detected, but where there was one, the behaviour initiated by an error was generally the most accurate. On these occasions it was not possible to maintain that the responding following an error was better than that following a correct IRT, since correct IRTs also initiated IRTs long enough to satisfy the (drl) criterion.

Once again the usefulness of rate measures must be questioned. No clear effects were detected in the present experiment, and the usual criticisms of preceding Chapters apply.

The results of the present experiment have served to indicate the complexity of the role of brief stimuli in second-order schedules. They have also served to illuminate the maintaining function of the reinforcing stimulus, and the issues raised by the immutability of the behaviours will be discussed at greater length at the end of this Section.

CHAPTER 12

Brief-stimulus manipulations on DRL(drl)

The final schedule reported in this Section has already been examined in part in Chapter 7. It was shown there that the DRL(drl) schedule may be treated as any other second-order schedule, and the usual analyses of DRL schedules also apply. The present experiment is an investigation of the effects of brief stimuli on this baseline.

METHOD

Subjects

Four naive, male albino rats served, each being maintained at 80% ad lib body weight by supplementary feeding after each session. Water was freely available at all times in the home cage. At the start of the experiment each of the animals was 250 ± 20 days old.

Apparatus

The standard experimental chamber was used. The tone was 0.75 sec in duration, 100 Hz frequency, and 90 ± 2 db intensity. It was clearly audible to a human observer above the noise (60 ± 2 db) of an exhaust fan.

Procedure

After lever training and 50 reinforcements under a continuous reinforcement schedule, two of the rats (G-1 and G-2) were exposed to a DRL 10-sec schedule, while the other two (G-3 and G-4) were exposed to DRL 5-sec. After the behaviour had stabilised, these schedules were brought under the control of an overall DRL 30-sec schedule. The same procedure was then followed as for the other experiments in this Section. First S^N was in operation, then S^P, and then back to S^N. After this sequence had been completed, the original baseline DRL schedule was re-instated.

Table 12:1 shows the number of sessions under each condition.

RESULTS

There are two basic distributions which are obtained from the data. One is the distribution in time of lever presses, and the other is the distribution in time of components. The former - the overall IRT distribution - is shown in Fig. 12:1. There was a clear effect of emitting longer IRTs on changing from tandem to S^N in all cases, except for G-1. There was an even more marked shift to the right on introducing S^P. Here, the distribution was centred more closely around the 30 sec value. Reversion to S^N had no effect (G-3), caused even sharper peaking (G-1), or shifted the peak back to the left (G-2 and G-4).

Figures 12:2 and 12:3 show the distribution of IRTs following correct responses or errors respectively. A limiting factor in both of these figures was the likelihood of, occasionally, too few instances of particular IRTs to enable either

TABLE 12:1

Experimental Conditions

SUBJECT	SCHEDULE	NUMBER OF TRAINING SESSIONS
G-1	DRL 10-sec	39
	DRL 30-sec(drl 10-sec)	49
	DRL 30-sec(drl 10-sec: S^N)	27
	DRL 30-sec(drl 10-sec: S^P)	28
	DRL 30-sec(drl 10-sec: S^N)	21
G-2	DRL 10-sec	36
	DRL 30-sec(drl 10-sec)	47
	DRL 30-sec(drl 10-sec: S^N)	27
	DRL 30-sec(drl 10-sec: S^P)	27
	DRL 30-sec(drl 10-sec: S^N)	20
G-3	DRL 5-sec	11
	DRL 30-sec(drl 5-sec)	54
	DRL 30-sec(drl 5-sec: S^N)	25
	DRL 30-sec(drl 5-sec: S^P)	31
	DRL 30-sec(drl 5-sec: S^N)	21
G-4	DRL 5-sec	13
	DRL 30-sec(drl 5-sec)	60
	DRL 30-sec(drl 5-sec: S^N)	29
	DRL 30-sec(drl 5-sec: S^P)	30
	DRL 30-sec(drl 5-sec: S^N)	23

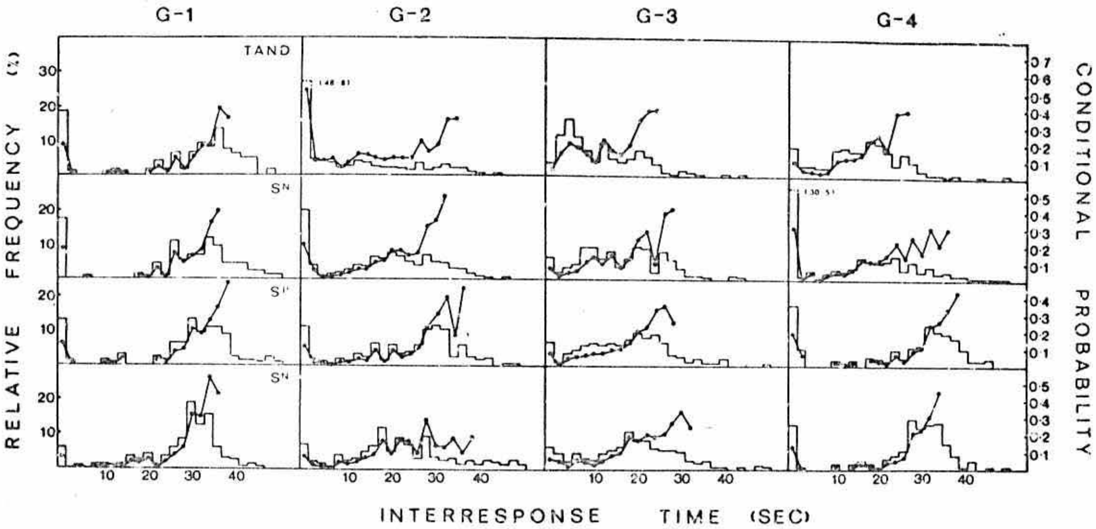


Figure 12:1

The relative frequency and conditional probability distributions of all the IRTs under each condition.

conditional probabilities or meaningful frequency distributions to be calculated. Where these limitations enabled effects to be seen, Fig. 12:2 shows that the behaviour initiated by a correct response was distributed around longer IRTs (30 sec or more) under the S^P condition. For both of the animals with (drl 10-sec) components, most of the bursts were occurring under the tandem condition. Indeed, for G-2, most of the responses made following a completed component in the tandem condition were bursts. Subject G-4 emitted mainly bursts following a paired stimulus, but was the only rat to do so.

The IRTs initiated by an error also showed few general effects due to the low incidence of errors made under some conditions by different animals. There were occasions where there was a tendency to emit longer IRTs on changing from tandem to S^N and then to S^P. There were no occasions where the opposite was true.

Consider now the temporal distribution of components. Unlike the other distributions presented in this thesis, these particular ones are unimodal

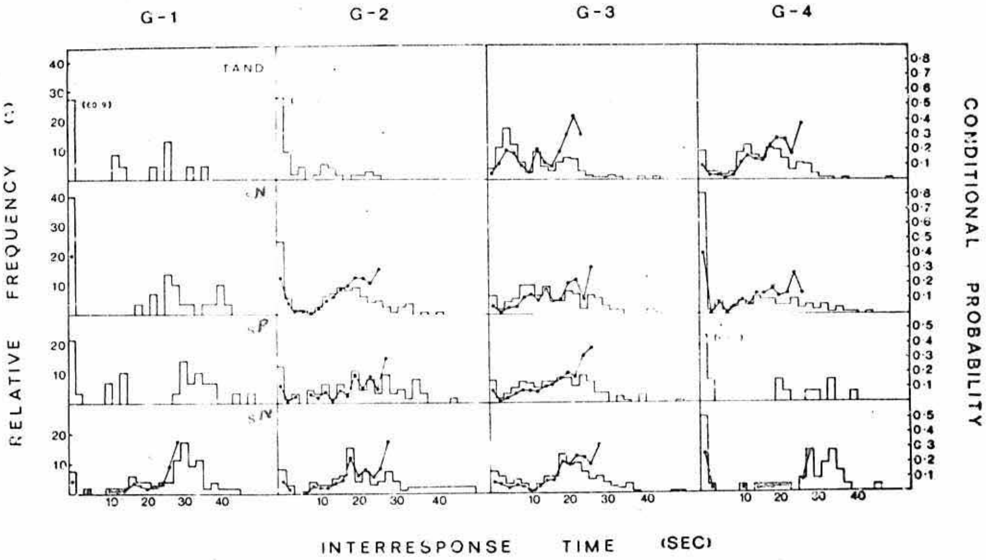


Figure 12:2

The relative frequency and conditional probability distributions of the IRTs following the completion of a non-reinforced (drl) component.

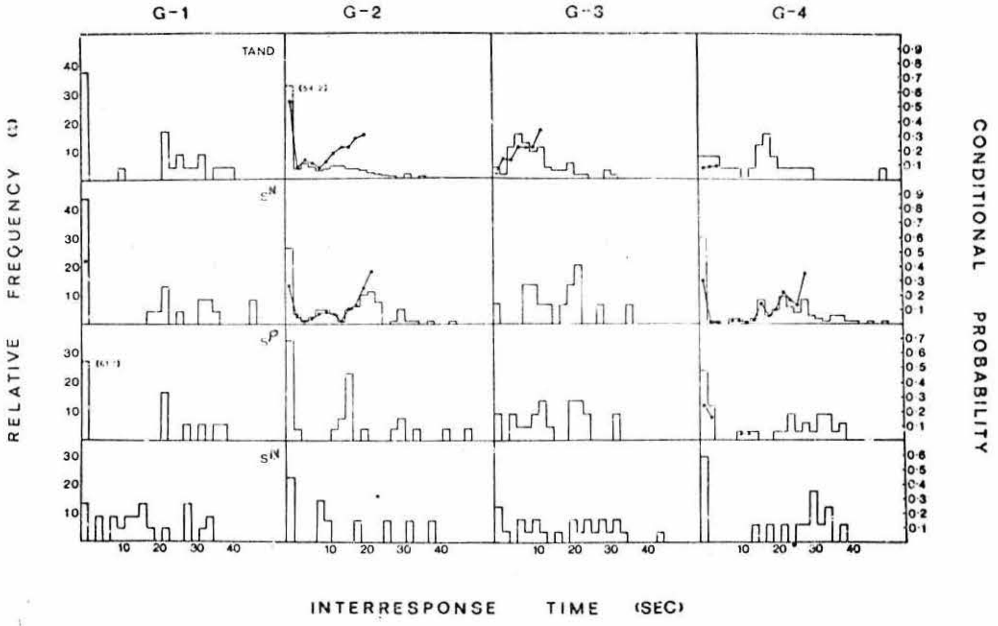


Figure 12:3

The relative frequency and conditional probability distributions of the IRTs following an error.

since it was not possible to have bursts of correct responses. (Each component took at least 5 sec or 10 sec to emit). Since the distributions are unimodal, they may be described in terms of the median value and interquartile range.

Figure 12:4 shows this for all the correct responses. The most accurate behaviour with respect to the DRL 30-sec schedule occurred for each subject except G-4 under the S^P condition, even though this meant a decrease in the duration of the intercomponent times for G-1. As the stimuli were changed, the intercomponent time durations of both of the subjects with (drl 5-sec) components increased. For 3 of the 4 rats, the effect of changing back to S^N from S^P was to decrease the duration of the median intercomponent time.

Two events could initiate a complete component: reinforcement or an error. Figure 12:5 shows the median and interquartile ranges of the postreinforcement pauses. For 3 of the 4 rats, there was no difference in pause between the S^N and S^P conditions, although for all subjects there was a decrease on changing from S^P to S^N. There was the smallest variance (i.e. sharpest peak) under the S^P condition. No systematic

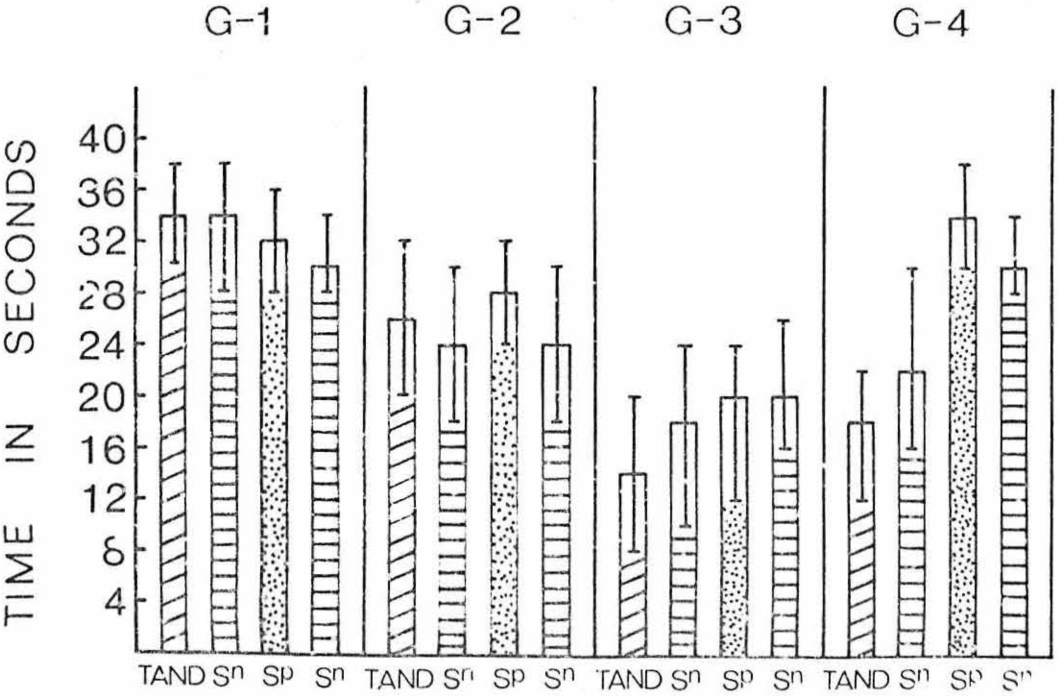


Figure 12:4

The median value, and interquartile range, of all intercomponent times.

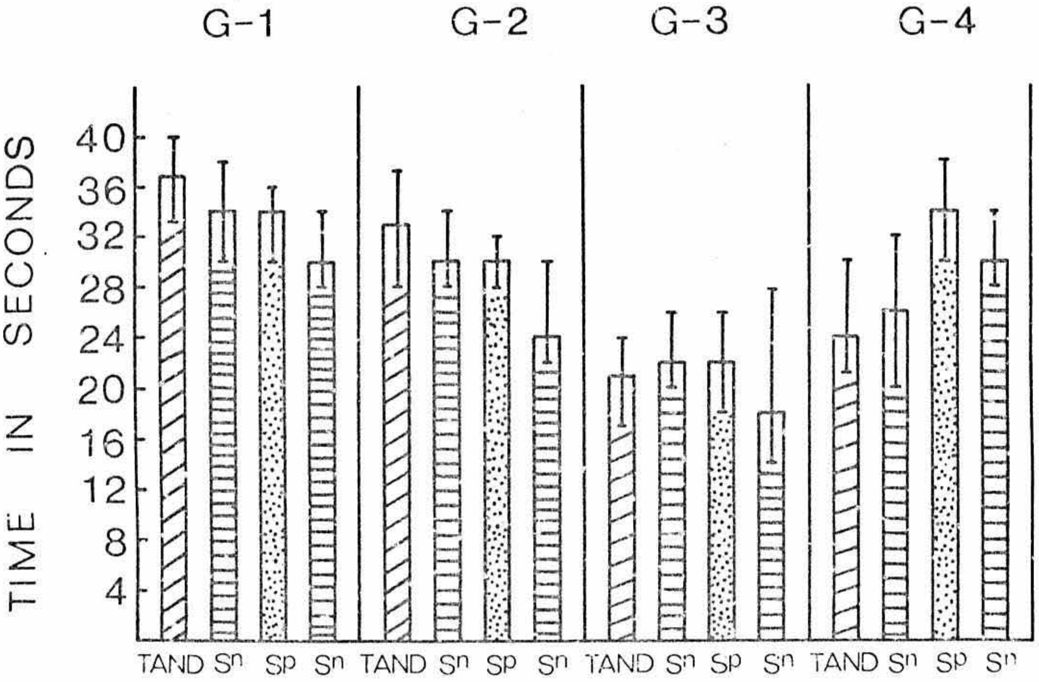


Figure 12:5

The median value, and interquartile range, of the intercomponent times following a reinforcement (the postreinforcement pause).

effect was evident on changing from tandem to S^N, nor was the longest or shortest postreinforcement pause in any particular condition.

The behaviour initiated by a component not occurring 30 sec after the previous component (an error) is shown in Fig. 12:6. There was always an increase in post-error pause on changing from S^N to S^P, although no really systematic effect of changing back from S^P to S^N, - two rats decreased their pauses, one was unaffected, and one increased his pause even more . In 3 out of 4 cases, the intercomponent time under the tandem condition was shortest, followed by that under S^N, with the longest under S^P. Table 12:2 shows both the postreinforcement and post-error pauses.

Rate data are shown in Fig. 12:7. The transition from tandem to S^N had no systematic effect on either the lever press rate or the component rate. Changing to S^P decreased the lever press rate of each subject, and decreased the component rate of 3 of the 4 rats. Reverting back to S^N either decreased further, or did not affect, the lever press rate, but increased the component rate of 3 of the animals.

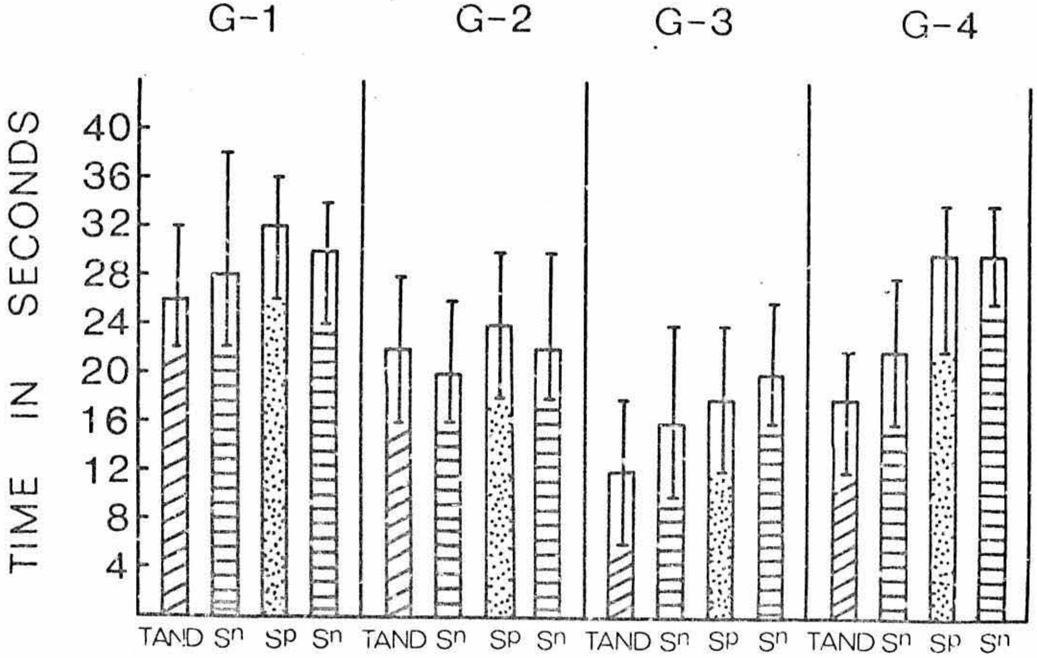


Figure 12:6

The median value, and interquartile range, of the intercomponent times following an intercomponent time of less than 30 sec duration.

TABLE 12:2

Comparison of Postreinforcement Pause and Postcomponent Pause Durations. Figures are Medians; Interquartile Ranges Shown in Parentheses. (sec)

SUBJECT	SCHEDULE	Post-Reinforcement Pause	Post-Component Pause
G-1	DRL 30-sec(drl 10-sec)	37(33-40)	26(22-32)
	DRL 30-sec(drl 10-sec: S^N)	34(30-38)	28(22-32)
	DRL 30-sec(drl 10-sec: S^P)	34(30-36)	32(26-36)
	DRL 30-sec(drl 10-sec: S^N)	30(28-34)	30(24-34)
G-2	DRL 30-sec(drl 10-sec)	33(28-37)	22(16-28)
	DRL 30-sec(drl 10-sec: S^N)	30(28-34)	20(16-26)
	DRL 30-sec(drl 10-sec: S^P)	30(28-32)	24(18-30)
	DRL 30-sec(drl 10-sec: S^N)	24(22-30)	22(18-30)
G-3	DRL 30-sec(drl 5-sec)	21(17-24)	12(6-18)
	DRL 30-sec(drl 5-sec: S^N)	22(20-26)	16(10-24)
	DRL 30-sec(drl 5-sec: S^P)	22(18-26)	18(12-24)
	DRL 30-sec(drl 5-sec: S^N)	18(14-28)	20(16-26)
G-4	DRL 30-sec(drl 5-sec)	24(21-30)	18(12-22)
	DRL 30-sec(drl 5-sec: S^N)	26(20-32)	22(16-28)
	DRL 30-sec(drl 5-sec: S^P)	34(30-38)	30(22-34)
	DRL 30-sec(drl 5-sec: S^N)	30(28-34)	30(26-34)

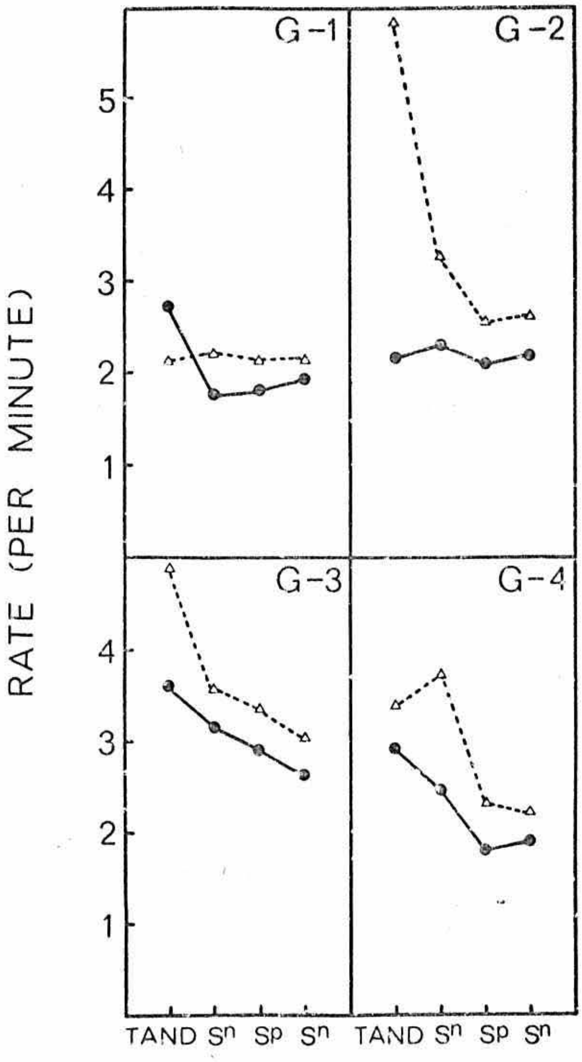


Figure 12:7

The rate measures. The triangles represent the overall rate of leverpressing; the closed circles represent the overall rate of emission of (drl) components;

DISCUSSION

The most useful dependent variables in this experiment were the different intercomponent time measures. Because these distributions were unimodal, they could be expressed quantitatively in the form of medians and interquartile ranges. This enabled a much easier assessment of the magnitude and direction of changes brought about by brief-stimulus manipulations. The usefulness of these measures reflects the emphasis of this thesis on the control exerted by the overall schedule, and the treatment of the component schedules as complex operants.

One general effect which was obtained was that of the least variability and greatest accuracy (being distributed closest to 30 sec) under the S^P condition. This effect was not always lost on returning to S^N.

As in Chapter 10, there was an anomoly on changing from S^N to S^P - one measure showed no effect, while another measure showed marked effects. Three of the rats showed no change in postreinforcement pause duration on changing to S^P, whereas all of the animals increased their postcomponent pause. Changing the nature of the brief stimulus, then, appears to have had little effect on the reinforcing stimulus, although it was an effective change, as evidenced by the change in the behaviour following it. Depending on the aspect of behaviour examined, there is evidence here for there being no functional difference between S^N and S^P (cf. Stubbs, 1971; Stubbs and Cohen, 1972), or there is evidence to support a functional distinction (cf. Kelleher, 1966 b; Marr, 1969).

The differences between the tandem and S^N conditions were not systematic. On changing back to S^N from S^P, however, there was generally a decrease in postreinforcement pause. This is unusual, since systematic changes on making this manipulation have rarely been reported.

The distributions of lever presses were also presented in the Results section (Figs. 12:1, 12:2, 12:3). Here, however, systematic differences between the stimulus conditions were less easily, and with less confidence, noted. A complicating factor proved to be the scarcity of instances from which to compile meaningful figures. There were occasionally large numbers of bursts which left no opportunities for longer IRTs to occur. This would seem to be an instance where the most detailed analysis of the behaviour fails to reveal functional relationships which a more molar analysis shows clearly. The need seems to be, not for an analysis in terms of the smallest units available, but in terms of the molecular aspects of the situation which are pertinent. In the present case, the most important information concerns the controlling influence of the overall schedule, less so the distribution of lever presses. Bigelow (1969) has made a similar point:

> "Recording as much behaviour as possible does not necessarily make readily apparent as much information as possible". (p.37)

One use of the IRT distributions was to evaluate the degree of control exerted by the component schedule, but it is clear from the distributions that this is quite low. In DRL(drl) schedules, although it is not the case in the other schedules discussed in this thesis, examination of the IRT distributions emphasises how easily the small amount of control by the component schedule may be lost on adding brief stimuli. This goes very much against the view held by some people (cf. Bigelow, 1971; Neuringer and Chung, 1967) that the function of a brief stimulus is to maintain the integrity of the complex operant (cf. Stubbs, 1971, for a discussion of this theory).

Comparing the behaviour initiated by a lever-press which satisfied the (drl) requirement with that initiated by one that did not (Figs. 12:2 and 12:3), where differences could be seen, they tended to be unpredictable. This leads one to the conclusion that effects of brief stimuli are more connected with overall schedule control than with component schedule control. This corroborates the remarks about the lack of control by the component schedule.

Rate data also suffered the same fate as IRT data in the present experiment because they, too, did not reveal any functional relationships. The lever press rates gave an indication of total behaviour output, affected greatly by bursts, while component rate did not change systematically.

The procedure employed in the present experiment has some similarities to those experiments where feedback has been given for responding under simple DRL schedules. This is even more apparent when one considers the component schedule as an operant. There are, unfortunately, few such experiments, but the general finding has been that feedback (usually a click) for non-criterion responses serves to reduce the number of bursts (Kelleher, Fry, and Cook, 1959). Topping and Pickering (1972) found that a brief electric shock presented contingent upon different bands of IRTs reduced the frequency of bursts. Kramer and Rilling (1969) also obtained the same effect when a blackout followed non-criterion responses.

These findings would only be directly relevant to the present study if it were possible to have bursts of components. Bursts of lever-presses have not been found in this thesis to have much relation to the experimental manipulations, but evidence has been presented that bursts are not simply due to a lack of feedback for responding (cf. Kramer and Rilling, 1969; Topping and Pickering, 1972), since there have been many examples in the present experiment, and throughout the thesis, of bursts following both S^N and S^P.

Other experimenters have suggested that component schedules react in much the same way as do lever-presses on simple schedules (cf. Blackman et al. 1970; Davison, 1969). This suggestion has been examined and subsequently modified in this thesis. A simple experiment to examine this with special reference to the present experiment would be a replication of this experiment using a simple DRL schedule. A brief stimulus would be made contingent on errors (S^N), and then on all lever presses (S^P). If there is an exact analogy between components and single responses, one would expect the most accurate temporal discrimination under the S^P condition, where the brief stimulus follows all responses.

While a clear brief-stimulus effect has been demonstrated in the present experiment, one of the most interesting points to arise has been the necessity to choose most carefully the dependent variables. It has been suggested that the choice must be made with consideration of the schedule requirements, and not simply to use the smallest unit possible. Furthermore, it has been noticed that this has been the only situation in Section III where the brief-stimulus effects have been mainly on the control exerted by the overall schedule.

GENERAL DISCUSSION

The final stage of each experiment presented in this Section was to return each subject to the original baseline DRL schedule, in order to assess the effect on the DRL behaviour of the extensive experimental history. These results are presented here, rather than at the end of each Chapter, because the behaviour on returning to DRL was essentially similar in all cases. There was an immediate transition to sharp, accurate temporal discrimination, with the IRTs spaced closely around the criterion. Selected examples of this baseline behaviour are shown in Fig. 12:8, and these are representative of the behaviour of all of the rats.

There is no indication here of metastability (Staddon, 1965), the phenomenon whereby the original behaviour cannot be obtained after an experimental history. This thesis, however, contains many other examples of metastability when changing from S^P back to S^N.

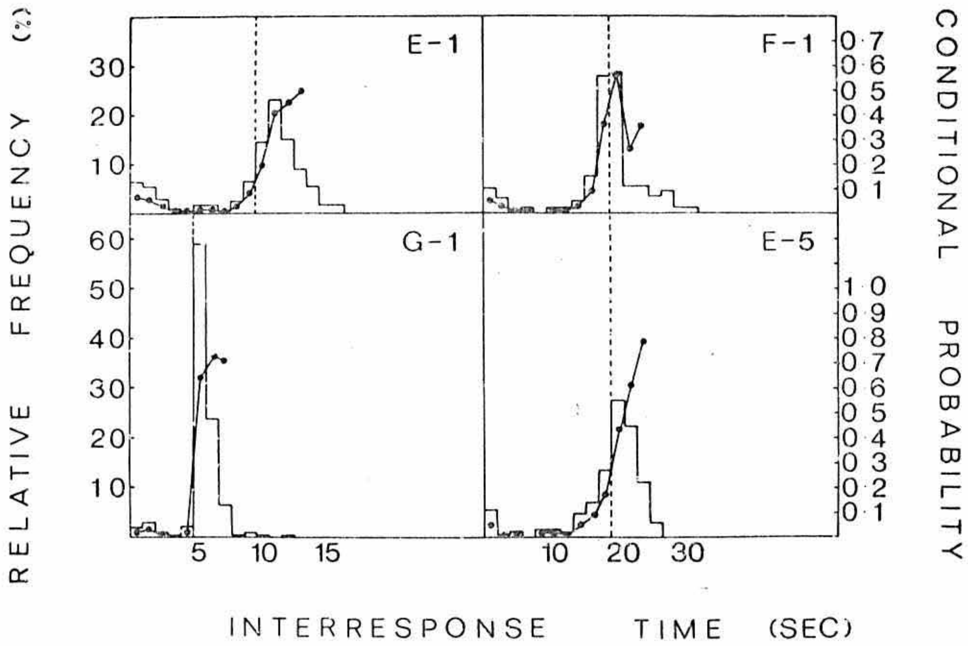


Figure 12:8

Relative frequency and conditional probability distributions from the final DRL condition. Shown here are some examples from four of the experiments.

Before assessing the general effect of the brief-stimulus manipulations, two points must be made. The first is that response patterning appropriate to DRL schedules has been obtained under all conditions, so the problem has really been one of assessing differences in patterning. In much of the second-order schedule literature, the concept of response patterning has been treated in a more general way, and it has been sufficient to report the presence or absence of patterning under different conditions. In those cases where the degree of patterning has been reported, it has taken the form of Index of Curvature (cf. Fry, Kelleher, and Cook, 1960) or quarter-life (cf. Kelleher, 1966 b), but even here, little or no patterning has been obtained under the tandem conditions. The present experiments demonstrated that it is possible to obtain recognisable schedule patterning under tandem conditions, at least when DRL schedules are used as components.

The second point concerns the measurement and representation of this degree of patterning. Since we are primarily interested in changes in the pattern of responding brought about by changing the stimulus conditions, it is convenient to have a way of expressing this quantitatively. Such a form does not, unfortunately, exist for describing DRL behaviour. Typically, the temporal distribution of responses under a DRL schedule is bimodal, and this cannot be simply expressed. Hodos (1966) has suggested a method of transposing the frequency data, but this has not become a generally accepted procedure. Perhaps one reason for this is that certain assumptions about the behaviour have to be made. For example, bursts are excluded, as being an 'unimportant' aspect of the situation.

In Chapter 12, the intercomponent time distributions under DRL (drl) lent themselves to expression in the form of a median and interquartile range, since these distributions were unimodal. Likewise the distribution of IRTs following reinforcement (the postreinforcement pauses) has been so treated in all of the Chapters. With these exceptions, however, the description of behaviour under the schedules reported here has included qualitative terms such as "sharpening", "accuracy", etc. These terms are generally self-explanatory. A "sharper" distribution is one which has a smaller spread of IRTs, and an "accurate" one is one which is centred on or close to the IRT required by the schedule.

Overall views of behaviour (in the form of overall IRT distributions) indicated a general effect of changing the behaviour towards that normally generated by DRL schedules as S^N was added to the tandem condition. There were occasionally instances where this was not so. This finding contradicts many of the conclusions of other studies (cf. Byrd and Marr, 1969; Marr, 1969), although some authors have occasionally reported patterning with S^N conditions (cf. Kelleher, Fry, and Cook, 1964; Neuringer and Chung, 1967). This excludes Stubbs (1971) and Stubbs and Cohen (1972) who obtained the same degree of patterning under S^N as under S^P.

On changing the stimulus to S^P in the present experiments, there was generally further improvement in the patterning. This is in agreement with the bulk of second-order schedule literature, which maintains that S^P engenders patterning appropriate to the component schedule.

The analyses presented in the preceding Chapters have considered separately the behaviour initiated by (i) reinforcement, (ii) a completed component, and (iii) an error.

(i) Postreinforcement behaviour

Under the RR, FR, and DRL overall schedules, changing from S^N to S^P brought about an increase in the postreinforcement pause duration. There was also an increase in the case of 2 of the rats under each of the other schedules. Although not completely unanimously, most of the rats, regardless of the overall schedule, lengthened their postreinforcement pause on changing to S^P. This finding is in direct contradiction to that of de Lorge (1971), who reported a reliable decrease under FR(VI) schedules. In this case, however, de Lorge (1971) did not actually observe the duration of the pause decreasing on changing from S^N to S^P. He noted instead the difference between the S^N and S^P components of a multiple schedule.

The change from the tandem to the S^N condition did not produce such a reliable effect. The pause decreased under RR and DRL schedules, and increased under FI and VI. Also equivocal was the result of changing from S^P to S^N. Some animals increased their pause length, some decreased, while some were unaffected.

Regardless of other changes, the reinforcer always set the occasion for an IRT longer than that required by the component schedule, and consequently cannot be considered as setting the occasion for (drl) behaviour. It is well documented that the length of the postreinforcement pause is a function of the temporal parameters of the overall schedule (cf. Ferster and Skinner, 1957; Schneider, 1969; Staddon, 1974). It is not surprising, therefore, that the postreinforcement pause was not strongly under the control of the component schedule. Evidence is accumulating, however, that factors other than the temporal parameters may affect the postreinforcement pause length. These factors include the concentration of the reinforcer (Lowe, Davey, and Harzem, 1974), rate of reinforcement (Carr and Reynolds, 1974), the duration of reinforcement (Staddon, 1970), and the number of responses emitted for reinforcement (Crossman, Heaps, Nunes, and Alferink, 1974; Rilling, 1967). In the present experiments, the duration of the pause was shown to be also dependent on the differential consequences of emitting a correct response. The mechanism by which this takes place is not understood, although from the evidence presented in Chapter 10 it is unlikely to be anything as simple as changes in the interreinforcement interval brought about by behaviour changes caused by manipulating the stimulus conditions.

It appears that the postreinforcement pause is a complex part of the behaviour stream, and is one which is affected by many variables. One way to approach this topic is by means of a consideration of changes in the discriminative or controlling properties of the reinforcer. Research in other fields has shown that the postreinforcement pause is affected by the number of stimulus "elements" present at reinforcement (cf. Kello , 1972). The general effect has been one of a shortening of pause as the number of elements is decreased. The present experiments, and one reported by Davey, Harzem, and Lowe (1975) show that the reverse of this is also true - the pause will lengthen if extra elements are added. This may be described as an increase in temporal control brought about by increasing the stimulus complex at reinforcement. It may be that this is a general phenomenon underlying the effect of changing from S^N to S^P. The body of literature on stimulus intensity dynamism (cf. Gray, 1965) would support this tentative conclusion.

(ii) Postcomponent behaviour

Whereas the major change in postreinforcement pause occurred on transition from S^N to S^P, the most systematic change in postcomponent behaviour occurred on transition from tandem to S^N. When an extra stimulus element was added to the reinforcer, there was an increase in temporal control by the reinforcer. When an extra element was added at the completion of a correct response, the control by that event was increased, and took the form of an increase in the accuracy of the component behaviour. When this element was paired with food, there was an increase in control in the two variable schedules and the DRL overall schedule, but not in the case of the two fixed schedules. This may have been due to the high degree of temporal control exerted on the fixed schedules (cf. Chapters 3, 6, 9, and 10) leaving much less scope for improvement in the control by the brief-stimulus. There was much less temporal control on the variable schedules and consequently more room for improvement.

(iii) Posterror behaviour

Only in occasional instances were differences in behaviour initiated by an error observed under the different stimulus conditions. There were improvements on changing from tandem to S^N (B-1, and E-3) or on changing from S^N to S^P (B-1, B-2, E-5, E-4, E-3, and rats on FI(drl)). There were more occasions when there was no change in the behaviour following a mistake. Since the immediate consequences of an error were identical under each stimulus condition, any differences must have been due to generalisation of effects, these effects being

(a) the effect of changing from tandem to S^N
(b) the effect of changing from S^N to S^P

While recognising the complexity of postreinforcement and postcomponent behaviour, it seems clear that posterror behaviour was also determined by multiple factors. The present experiments do little more than to point out the existence of these complex interactions. This factor has largely been ignored in second-order schedule literature, and cannot be investigated fully by means of the gross analyses often used.

These three separate behaviours, and the differential effects on them of stimulus manipulations, indicate some of the sources of stimulus control which might be present in second-order schedules. Firstly, there is the control exerted by the overall schedule, which has been discussed in this thesis in terms of the maintaining and controlling function of the reinforcer. The component behaviour is maintained by food, while the postreinforcement pause is controlled by the food and associated stimuli. The controlling function is apparently affected by changing the brief stimulus from S^N to S^P, a phenomenon reported in the literature in other contexts (cf. Davey et al. 1975; Kello, 1972). The maintaining function is slightly more difficult to deal with, since it is not clear exactly what attributes it possesses. Indeed, some authors seem to be in favour of relegating the maintaining function to a minor role (cf. Bindra, 1974; Estes, 1972). Schuster (1969) has suggested that a functional analysis of stimulus effects is served better by concentrating on the behaviour initiated by stimuli, but he did not dismiss the likelihood of there being a reinforcing or maintaining function.

The second type of schedule control in the situation is the control exerted by the component schedule, which takes the form of characteristic patterning of lever presses. When control of this type is increased, there is an increase in the proportion of IRTs, which conform precisely with the schedule requirements. This type of control is affected by the addition of S^N to the tandem situation, and in some cases by the conversion of S^N to S^P. The former finding is concordant with the postreinforcement pause effect discussed above. This may be part of the general phenomenon of increasing control on adding extra stimulus elements to a situation. This topic has been reviewed elsewhere with respect to other situations (cf. Baker, 1968; Gray, 1965; Weiss, 1972).

Posterror behaviour gives another example of this second type of control, and was not systematically affected by the stimulus manipulations. It appears that there may be two aspects of the control by the component schedule. One is the control exerted by a correct response, the other is the control exerted by an error. The former is affected by stimulus changes, but the latter is not (since the consequences of an error remain constant). Note also that posterror behaviour was always the most accurate in the present schedules.

These observations on the component schedules control are in line with our understanding of behaviour under simple DRL schedules. An error on DRL initiates, with a high probability, an IRT long enough to satisfy the schedule criterion (cf. Ferraro et al. 1965). If the contingencies are so arranged, an error may even initiate behaviour which greatly increases the time to reinforcement (cf. Lowe, 1974). In the present experiments, errors initiated IRTs much closer to the (drl) criterion than those initiated by correct responses. There are many other published reports of behaviour without exteroceptive consequences exerting powerful control over the subsequent behaviour (cf. Angle, 1970; Logan, 1967; Sidman, 1966).

The control exerted by correct responses in the present experiments seems to fall part way between the overall schedule control and the component schedule control. This is another example of the interaction between the two types of control which has been discussed in previous Sections.

One situation in this thesis where the conflict between overall and component schedule control was quite clear was in the DRL(drl) schedule. The overall schedule here exerted far more control than did the component schedule. That the component schedule exerted some degree of control was obvious from the difference in behaviour between the subjects with (drl 5-sec) and (drl 10-sec) components.

There were some dependent variables which did not show systematic effects between the stimulus conditions. These included the rate measures, and the within-schedule component durations. They have been included to illustrate the need for careful choice of measures, where real relationships exist, but the behaviour changes might be small and easily obscured.

The experimental design has been uncomplicated, but ensured that any behaviour observed during the S^N condition was not due to a previous pairing of that stimulus with food. Stubbs (1971) has pointed out that many earlier experiments had not taken this precaution. Also, the same tone was used here as both S^N and S^P, removing the possibility of stimulus-specific effects. The intensity of the stimuli, however, was different in different experiments, although it remained constant within a particular experiment.

In many cases, the behaviour engendered by the first presentation of S^N was not obtained under the second presentation of that condition. It might be thought to be important that the effects of any independent variable should be shown to be reversible, but it has been shown here, and by others (cf. Cohen et al. 1973; Staddon, 1965) that behaviour is not totally elastic. Many authors are now examining the different behaviours occasioned by the same scheduling arrangements due to different experimental histories (cf. Alleman and Zeiler, 1974), and the irreversibility experienced in the present experiments may be another example of this phenomenon.

A more general aspect of the situation which has not been examined here is that the effects of brief stimuli may be dependent to some degree on the extent of the patterning present at the time. This might modify considerably the effects predicted by theories not taking this possibility into account.

How, then, do the results from the present experiments compare with those of other second-order schedule studies? This is a difficult question to answer for three reasons.

(i) Very few studies have used (drl) components, and those that have do not present data detailed enough to assess differences between the stimulus conditions.

(ii) Overall, there is a paucity of studies comparing tandem, S^N, and S^P conditions. Most studies have looked only at two of these conditions.

(iii) The results of second-order schedule experiments have generally been presented in such a way that detailed differences, of the sort presented here, are not visible.

The literature is unanimous in ascribing the most accurate schedule control to the S^P condition, and this was usually the case in the present experiments. There is dissention concerning the effects of S^N, most authors finding little or no patterning (cf. Kelleher, 1966 b; Marr, 1969), while Stubbs and his co-workers (cf. Stubbs, 1971; Stubbs and Cohen, 1972) obtaining the same patterning under S^N as under S^P.

The results of the present experiment do not accord fully with either of these positions. However, very few (drl) components have been used previously, and it may be that the results given here are (drl) specific. Stubbs (1971) suggested that the use of components which have little predictive power with respect to the occurrence of food (e.g. VI and VR) might provide the conditions for a difference between

S^N and S^P to exist, since conditioned reinforcing effects would be stronger than discriminative effects. With (drl) components both functions may appear, since there ought to be more predictive power than with (VR) and (VI), but less than with (FR) and (FI).

The first explanations of brief-stimulus effects were in terms of conditioned reinforcement, since it was thought possible to maintain patterning only under the S^P condition. When instances of patterning under S^N were observed, a discriminative function was suggested. In practice, however, these two are very difficult, if not impossible to separate. Schuster (1969) has suggested that a functional analysis of brief-stimulus effects should not rely on the concept of conditioned reinforcement, since extra theoretical constructs are needed which are unnecessary if we describe the effects in terms of a discriminative function (cf. also Baum, 1973). However, we must also postulate factors which change the discriminative function with such things as changes in the distance to reinforcement, and whether or not the stimulus has a close temporal association with food. Furthermore, it is difficult to maintain that food has only discriminative (controlling) and not reinforcing (maintaining) properties. Current thinking in the experimental analysis of behaviour is that there is little essential difference between food and other stimuli (cf. Schoenfeld and Cole, 1972), and it seems reasonable to assume that brief-stimuli have similar functions to those of food.

A major problem, then, is one of the grammar of behaviour. Naming effects does not explain them (in the sense of identifying necessary and sufficient conditions). The functional relationships described in this Section might prove to be part of the answer to the question "how do brief-stimuli have their effects on behaviour in these situations".

CONCLUDING COMMENTS

The investigations into the nature of behaviour generated by second-order schedules presented in this thesis may be considered to have raised more questions than it has answered. One of the main queries raised at the start of the research was 'to what extent is the nature of the operant an important factor, and how valuable will be a treatment of second-order schedules as schedules of complex operants?'.

A comprehensive review of the available literature on second-order schedules revealed some interesting results.

(i) Very rarely have second-order schedules been treated as schedules of complex operants, even though Kelleher's (1966b) original definition made this characteristic apparent.

(ii) There appear to be two internally consistent, but contradictory bodies of evidence. One states quite clearly that only a brief paired stimulus will maintain typical component behaviour (cf. Kelleher, 1966b), while the other holds that both paired and non-paired brief stimuli have this effect (cf. Stubbs, 1971).

(iii) Common to the majority of second-order schedule studies was a reliance upon response rate as a dependant variable, and a failure to utilise other, possibly more relevant, measures.

(iv) The variety of component schedules that have been studied is very limited. For example, there are no published reports using (VR) components, and only one report of a second-order schedule with (VI) components.

Section I showed that there was an interaction between the control exerted by the overall and component schedules. Manipulating the parameters of the overall schedule had a reliable effect on the component behaviour, and the nature of the operant determined, to some extent, the character of the overall schedule control. A distinction between the maintaining and controlling functions of a stimulus was useful here in evaluating these effects.

Section II specifically investigated the way in which the nature of the operant may affect the overall schedule control, and it was pointed out that the grammar of behaviour is an important consideration in the clarification of certain conceptual issues. A distinction between functional and descriptive operants was found to be essential.

In Section III, a series of experiments was reported in which the effects of brief stimuli were evaluated. It was shown that traditional explanations were inadequate, since the non-paired stimulus had effects which were, in some sense, intermediate between the effects of no stimulus and a paired stimulus. Further analysis showed that the effects of paired or non-paired stimuli were actually on different aspects of the behaviour. The main effect of adding a paired stimulus was to increase the duration of the postreinforcement pause, while the major effect of adding a non-paired stimulus was to increase the postcomponent discrimination.

These results would seem to fit into a general theory of increasing control as the intensity of a stimulus is increased (cf. Davey et al. 1975; Gray, 1965; Kello, 1972). This alleviates the necessity to conceive of brief stimulus effects as being due to conditioned reinforcement, and thus removes many attendant complexities (cf. Schuster, 1969; Stubbs, 1971). It is, however, quite within the frame of reference of a discriminative stimulus - type explanation. It seems to be the case that both of these are quite compatible, and choice of one, rather than the other, will be determined by personal preference. A recent suggestion by Starr and Staddon (1974) that 'memorability' of the stimulus is important is not supported by the 'selective' action obtained here. In fact, the Starr and Staddon (1974) explanation may also be faulted on empirical grounds, since they suggest that those studies where a difference between S^N and S^P has not been found have used long interreinforcement times, and, hence, S^P is remembered better than is S^N. However, de Lorge (1969) used component durations of the same length as Stubbs (1971), and de Lorge (1971) and Stubbs (1969) used even shorter durations.

There have been other issues of more general importance arising out of this thesis. It has become evident that not all measures of responding are useful in identifying functional relationships. It is not simply a matter of choosing the easiest-to-record, or the most molecular, aspect of behaviour. As in the rest of Nature, where there are certain commonly occurring "units", it seems that in behaviour too there are "natural lines of fracture" (Skinner, 1938), and we must take these into account when choosing our units of behaviour.

In almost every Chapter, the relevance of previous behaviour patterns and schedule contingencies to present behaviour has been discussed. This is a matter which is often overlooked in the experimental analysis of behaviour, but one which has been shown to be important here, and in other contexts (cf. Alleman and Zeiler, 1974). The possibility has not been examined here that changes in patterning brought about by brief stimulus changes might depend on previous history, but it is a very real possibility nevertheless. Indeed, such an interaction might be expected, since other complex interactions have been identified.

The remarks by Robert C. Bolles which preface this thesis have guided the research presented here. This has resulted in there being proposed no grand theoretical system to explain the relationships obtained. There has been, instead, an attempt to describe accurately the conditions under which certain response patterns occur, and a limited amount of empirico-inductive reasoning as to possible general effects.

If the purpose of science is in some way to explain Nature, I believe that the process of description engaged in here is a part of that process of explanation. Although this is not the place in which to discuss the relationship of description to explanation, I think that it is difficult to find fault with the position exemplified in Baum (1974):

> "...every explanation can be stated in the form: "A occurs because it is an instance of B". The observation A may be an event ("Why does the response occur?") or it may be a relation ("Why does Y increase when X increases?"), and the explanatory term B may be a relation ("When conditions L, M and N are met, then the response occurs") or a law ("The relation Y=f(x) is a special case of W=F(Z)").
>
> If an explanation consists essentially in identification, then it must be logically identical with description". (p.450)

It is quite possible to argue that the descriptions I have presented in this thesis are incomplete or inadequate, but to this charge I close with words attributed to Sir Arthur Eddington by the Astrophysics Journal (1945), and quoted in an anthology compiled by R.L. Weber (1973):

"When an investigator has developed a formula which gives a complete representation of the phenomena within a certain range, he may be prone to satisfaction. Would it not be wiser if he should say 'Foiled again! I can find out no more about Nature along this line'".

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