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DETERMINANTS OF POST-REINFORCEMENT PAUSES ON FIXED-RATIO SCHEDULES

By

MONA SALMAN

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CONTENTS

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I wish to say that without the careful guidance given me by Professor Jack D. Keehn it would have been impossible for me to write the present thesis. I don't believe I possess the right words to express my appreciation of his sincere and invaluable help. I can only say that I gratefully acknowledge his efforts, and never shall forget the interest and enthusiasm he has shown throughout.

I want further to thank Mr. Douglas Ramsay for his interesting suggestions, and his willingness to help whenever help was needed.

Thanks are also due to Professor E.T. Prothro for his helpful comments.

Chapter I

INTRODUCING THE PROBLEM

Reinforcement is one of the best known factors controlling behaviour. Not only does it fixate new forms of behaviour in the repertory of the organism but it also maintains these responses at certain probability levels. Withdrawal of reinforcement results in extinction, though not necessarily immediate extinction. In the laboratory an easy way to examine the probability of a response is to select for study a response which can be easily identified, and the occurrences of which can be easily counted. These requirements are met by the lever pressing apparatus technique devised by B.F. Skinner.[1] In the Skinner Box the arrangements are such that only the emission of the chosen response sets the automatic scheduling and the recording apparatus into operation. The rate of response is shown on a cumulative graphic recorder.

For the frequency of a response to be maintained it is not necessary to reinforce every response. A response may be reinforced intermittently under what is called a schedule of reinforcement. Schedules of reinforcement are numerous, and the most important of them are the 'fixed ratio' (FR) schedule of reinforcement and the 'fixed interval' (FI) schedule of reinforcement. In the former schedule a fixed number of responses must be made for reinforcement to be presented,

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[1] B.F. Skinner, "Some Contributions of an Experimental Analysis of Behaviour to Psychology as a Whole," Amer. Psychol., 1953, 8, p. 69-78.

while in the latter schedule reinforcement is contingent upon the first response emitted after a fixed interval of time (since the presentation of the preceding reinforcement) has passed. When the intervals between reinforcements are made to vary around a certain mean value the schedule is identified as a 'variable interval' (VI) schedule of reinforcement. When the number of responses required between each reinforcement is made to vary around a certain mean value the schedule is identified as a 'variable ratio' (VR) schedule of reinforcement. Two or more schedules may be combined to form a 'multiple' or a 'mixed' schedule of reinforcement. In a 'multiple' (mult) schedule of reinforcement two different schedules, each correlated with a different stimulus, are made to alternate, regularly or at random. The 'mixed' (mix) schedules, on the other hand, are the same as the multiple schedules except that no stimuli are paired with the component schedules.

When animals are put on a fixed ratio or a fixed interval schedule of reinforcement their typical behaviour is to make the required number of responses or to wait the required interval, and then pause immediately after reinforcement before they start responding again. Experiments which document this fact are many. Perhaps it is only fair to point to Ferster and Skinner as furnishing, in their book Schedules of Reinforcement, the most extensive documentary evidence.[2]

It has further been shown that, generally, the greater the fixed ratio the longer the pause following reinforcemnt. Ferster and Skinner describe several experiments illustrating this fact. Using

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[2] C.B. Ferster, B.F. Skinner, Schedules of Reinforcement, p. 39-132, 133-325

birds as subjects they have shown that under short fixed ratios, ranging from FR20 to FR60, the animals typically pause for very few seconds after reinforcement before they resume responding again. The pauses generated are so slight that they are almost invisible in the graphic records.[3] Under fixed ratios of 120 and 200, on the other hand, the pauses extend to a few minutes after each reinforcement. Such intermediate fixed ratios typically generate pauses long enough to yield cumulative curves of a steplike fashion.[4] Furthermore, a transition from a large fixed ratio to a short fixed ratio has been shown gradually to shorten or eliminate completely the pause after reinforcement. The pause reappears again, gradually, if the ratio is set back at its former high value.[5] The correlation of pause length with size of ratio is further demonstrated in an experiment conducted on 3 birds reinforced on *mult* FR60FR200. Each of the two components of the schedule was to remain in effect for the full day's session. The colour of the key to be pecked by the animal also changed with the change in the schedule. It was possible thus to obtain separate records of the birds' performance on each of the schedules. Results show discrimination to have developed fairly well by the 12th and 13th days; the birds were making short pauses under the FR60 component of the multiple schedule, and long pauses under the FR200 component.[6] A final important experiment illustrating the relationship between pause length and ratio size was

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[3] *Ibid.* p. 48-51

[4] *Ibid.* p. 51, 52

[5] *Ibid.* p. 54, 55

[6] *Ibid.* p. 531

conducted by Skinner in the 1930's. He trained 2 groups of rats to bar press for food and, gradually, built them up to FR16. The rats were left to stabilize at this ratio for 3 days after which they were advanced to progressively higher ratios of 48, 64, 96, and 192:1. After the animals stabilized for 3 days at each of the above ratios the first phase of the experiment was ended. The second phase involved the reinforcement of each rat for periods of three days at one or other of the ratios; 48, 96, 192, selected at random.[7] Measurements of the pause at all ratios were taken for every rat and the results averaged. It was found that the average pause was 73 seconds at FR48; 96 seconds at FR96; and 120 seconds at FR192. Every one of the rats had the same trend as the average; increases in the length of the pause followed increases in the size of the fixed ratio.[8]

One of the important explanations given for the post-reinforcement pauses on FR and FI schedules of reinforcement is based on the fact that the presentation of the reinforcement itself generates behaviour in the organism which competes with the response under observation. The competing behaviour involves responses such as moving towards the magazine, biting, chewing, licking, swallowing, etc. In other words, the reinforcement generates the chain of responses involved in consummation. This, plus the fact that responses (at least the first response) immediately after reinforcement are never reinforced (a fact implied in the definition of FR and FI schedules), ascribe S^{Δ} properties to the reinforcement itself

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[7] B.F. Skinner, The Behaviour of Organisms, p. 286

[8] *Ibid.* p. 298

strictly speaking, to its after-effects. The animal consequently stops responding until the S^{Δ} properties of the reinforcement wane by the passage of time.[9] On the other hand, as reinforcement is contingent upon a burst of responding, this burst of responding constitutes an S^D so that when the animal next begins to respond it produces the S^D for further responding, and so the animal responds up to the next reinforcement.

Explanations of the post-reinforcement pauses as such; in terms of the S^{Δ} properties of the reinforcement itself and in terms of the S^D properties of responding, have some empirical support. Performance of animals on variable schedules of reinforcement have demonstrated the fact that post-reinforcement pauses occur because responses made immediately after are never reinforced.[10] Under such schedules as variable ratio and interval, where first responses following reinforcement are occasionally reinforced, post-reinforcement pauses were found to disappear. Predictions about the next reinforcement is impossible on these schedules, and the organism adjusts by holding to a uniform rate which it maintains for several hours.[11]

That the post-reinforcement pause is a function of the temporal properties of reinforcement and the response sequence leading to it has been demonstrated by Ferster by means of a "time-out of the experiment" technique.[12] A time-out is defined as that period of time during which the organism is prevented from making the response under study.[13] This can be achieved by many ways such as taking the animal away from the experimental

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[9] Ibid. p. 288

[10] Ferster and Skinner, op. cit., p. 391-413, 326-39

[11] B.F. Skinner, Science and Human Behaviour, p. 102, 104

[12] Ferster, Charles B., "Use of the Blackout in the Investigation of Temporal Discrimination in Fixed-Interval Reinforcement," J. Exp. Psychol., 1954, Vol. 47, No. 2, p. 69

[13] C.B. Ferster & B.F. Skinner, Schedules of Reinforcement, p. 34

box, or, in the case of birds, turning off the lights in the experimental chamber. In his study Ferster argues that if a time-out period, introduced immediately after reinforcement on fixed interval schedules, eliminates the rate change (or the low probability of response) which is typical during the early part of the interval on such schedules, <u>then</u> that change in rate can be attributed to the temporal properties of the stimulus. Naturally, the length of the time-out period required to eliminate the temporal discrimination must not be shorter than the time during which the stimulus is usually effective in controlling the probability of the response. Since pigeons are known not to peck in the dark unless trained otherwise, Ferster chose for his purposes simply to turn off the light in the experimental box following the delivery of the reinforcement; thus, introducing a time-out period known as the **blackout.** Two pigeons, with a rich experience on interval schedules and time-out, were used for the first experiment. They were put on a 90 sec. fixed interval schedule and allowed to stabilize. That is, they were allowed enough time for their performance to become uniform, or less varied from day to day. After the administration of 1200 reinforcements, when the pauses became consistent, a 30 sec. blackout was made to follow every 10th reinforcement. The experiment lasted for 6 days, and the intervals with and without blackouts were then compared. The results showed that whenever a blackout period was made contingent upon the reinforcement the pause at the beginning of the interval (as measured from the time the blackout period was terminated) was significantly decreased. The experiment demonstrated that the reinforcing stimulus does have temporal properties responsible for the low rate at the beginning of the interval. When the blackout was introduced it served to eliminate the temporal discrimination and thus, at the start of the interval (after the termination of the blackout period) the animal began to respond almost immediately. In a second experiment the S^D properties of the response sequence prior to reinforcement was investigated. Two pigeons with past experience on long fixed intervals were used. They were put on a 45-min. FI schedule every day from morning till evening and allowed to stabilize. After 6 days, when the pause became consistent, and when a few hundred reinforcements were secured by each of the animals, a 20-min. blackout period was made contingent upon each reinforcement. The results showed 2 major effects of the blackout; a) the pauses were significantly extended (as measured after the blackout period was terminated) and b) the total number of responses made during the first five minutes of the interval was significantly decreased. The experiment demonstrated that the preceding response sequence, in a 45-min. FI, is a stimulus with temporal properties responsible for the behaviour of the animal in the interval that follows. Normally the S^D properties of the pre-reinforcement run,which the investigator calls 'the carry-over', have the effect of generating a high rate quickly after reinforcement. (Since the number of responses and reinforcement are correlated). However, this did not happen when the blackout was introduced because the blackout eliminated the temporal properties of the pre-reinforcement run with the result that the onset of the post-reinforcement high rate was postponed. Ferster thus came to the conclusion that "following reinforcement two stimuli are present: the reinforcement stimulus, recent eating - which controls a low rate of responding - and the carry-over, number of pecks in the preceding interval which controls a high rate. The . . . pause which occurs just after reinforcement is under the control of recent eating; and the return to the rate prevailing at the time of reinforcement is under the control of the number of responses in the preceding interval."[14] In another experiment,

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[14] Ferster, op. cit. p. 72

with slight alterations in the method, the same results were found.

In Ferster's experiment it is the pre-reinforcement response sequence which controls the behaviour that follows the reinforcement. Since eliminating, or at least reducing, the S^D properties of the pre-reinforcement run (by means of the blackout) postponed the onset of post-reinforcement responding (i.e. extended the pause) it is possible to make the deduction that there is an inverse relationship between the strength of the S^D properties of the pre-reinforcement run and the length of the post-reinforcement pause. On fixed ratio schedules this would have the implication that it is the response sequence prior to the reinforcement which controls the post-reinforcement pause, <u>and</u> that shorter ratios - with a greater percentage of the component responses reinforced and, consequently, with a more powerful S^D[15] - would generate shorter pauses than would longer ratios. In other words, pauses are longer after long runs and shorter after short runs because of the relative weakness of the S^D of the long run with respect to the S^D of the short run.

Of course, such deductions are just <u>ad hoc</u> for the moment. In fact the application of the time out technique on fixed ratio schedules has not yielded consistent results. In <u>Schedules of Reinforcement</u> Ferster and Skinner report that under certain conditions the pauses characteristic of certain FR schedules disappear at the introduction of a time out following reinforcement, and under other conditions they increase in length. At ratios not exceeding 60, for example, post-reinforcement pauses have been shown consistently to disappear. At ratios exceeding 60, pigeons have been found to pause considerably longer at the introduction of the time-out following reinforcement. However,

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[15] B.F. Skinner, <u>The Behavior of Organisms</u>, p. 293

at such higher fixed ratios there are wide individual differences. Two pigeons reinforced on FR85, for example, yielded quite opposite results at the introduction of the time-out. The authors believe that the effect of time-out on FR schedules is still far from clear, and that the contradicting evidence present is enough to hinder arrival at a major conclusion.[16]

Another explanation of the pause following reinforcement on FR and FI schedules is implicit in Hull's theory of learning. Hull starts with the supposition that every response, or reaction to a stimulus, made by an organism produces in that organism a "certain increment of a fatigue-like substance or condition which constitutes a need for rest."[17] This need Hull considers to be a primary negative motivation or drive since it has the "innate capacity to produce a cessation of the activity which produced the state."[18] He calls the condition <u>reactive inhibition</u> (IR), and maintains that it is directly proportional, in amount, to the number of responses made by the organism. Reactive inhibition, thus, accumulates with increasing number of responses until a state is reached where the organism is no longer able to respond and the activity which has generated that need for rest in him is stopped. The mere passage of time following the response cessation results in a reduction of reactive inhibition.[19] Implicit in Hull's theory is, therefore, the deduction that longer runs in ratio schedules give rise to more reactive inhibition than do shorter runs and, consequently, require longer pauses for the negative drive to dissipate, <u>and</u>, that it is actually the response sequence preceding the reinforcement which determines the length of the following pause.

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[16] C.B. Ferster and B.F. Skinner, <u>Schedules of Reinforcement</u>, p. 116-132

[17] Clark Hull, <u>Principles of Behavior</u>, p. 391

[18] <u>Ibid.</u> p. 278

[19] <u>Ibid.</u> p. 300

It is clear from all that was said above that post-reinforcement pauses are explained in terms of the behaviour which precedes them. However, the pauses may as well be a function of the behaviour which comes _after_ them.[x] In other words, it is possible that the _post-reinforcement_ sequence of response is a determinant of the length of the post-reinforcement pauses. Skinner, for example, makes the following remark in his book _Science and Human Behavior_ (1953);

> Under ratios of reinforcement which can be sustained, the behavior eventually shows a very low probability just after reinforcement .... the effect is marked under high fixed ratios because the organism always has 'a long way to go' before the next reinforcement.[20]

Implicit in the above remark is obviously the assertion that it is the post-reinforcement response sequence which controls the length of the post-reinforcement pause.

The present study is an attempt to find out whether the post-reinforcement sequence of response does enter into the control of the post-reinforcement pause. The length of the pause may be a function of both pre- and post-reinforcement response sequences. The main problem of the present thesis is to obtain further information on this question of post-reinforcement pause determinants. In simple FR schedules it is impossible to tell which of the two response sequences determines the length of the pause; the pre-reinforcement response sequence or the post-reinforcement response sequence, since the pause is both preceded and followed by the same ratio. The relative contributions of the pre- and post-reinforcement runs in the control of the post-reinforcement pause can best be investigated by

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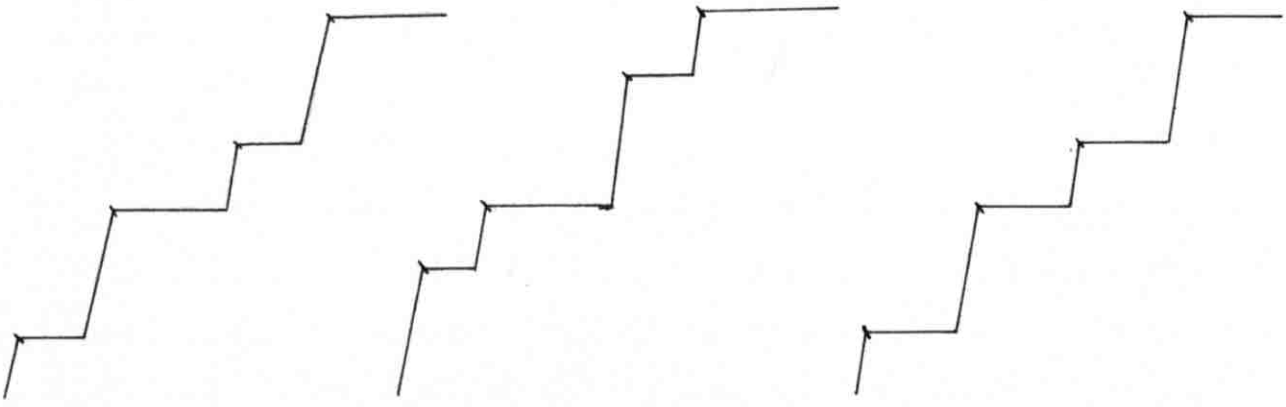
[x] This statement is not meant to be teleological. See page 40.

[20] B.F. Skinner, _Science and Human Behavior_, p. 103

the use of a multiple schedule of reinforcement, of the form FRxFRy, where the component ratios are made sufficiently unequal as to yield pauses of different lengths. At least three alternative results are possible; a) that long pauses follow the long runs and short pauses follow the short runs, in which case it can safely be said that pauses are solely under the control of the pre-reinforcement run. This follows logically from the already established fact that long pauses are correlated with large fixed ratios and short pauses with short fixed ratios, b) that long pauses follow the short runs and short pauses follow the long runs, in which case the post-reinforcement run would be responsible for the length of the pause, and, finally, c) that pauses of intermediate length would follow each of the runs. Graphically, the three alternatives would be respresented as follows;



a) b) c)

The thesis is also testing the possibility of other pause determinants which are of secondary importance.

Chapter II

METHOD

1. Subjects and Daily Routine

The subjects used in the present study were four male albino rats, S2, S3, S13, and S14. (Ages will be specified later). The animals, placed on a 22½ hrs. water-deprivation schedule which was continued for the duration of the experiment, were trained in daily sessions to bar press for water reinforcement. The daily routine was as follows: each animal, immediately before it was due into the experiment box, was weighed. The experimental session then, except for very few occasions, lasted for a period of 30 min. after which the animal was taken to its own cage to wait for half an hour before it was given water. Henceforward it was shifted to the drinking-cage, where water was given *ad libitum*, for 30 min. The animal was finally returned to its living cage. In the living cages food was available at all times for the duration of the experiment.

2. Apparatus

The animals were run in a modified Skinner Box, 9.5 in. in length, 8.5 in. in width, and 8.25 in. in height. These were the internal dimensions. The box was normally lit by a 6 watt bulb, and contained also a red and a green light installed in the same wall holding the lever. The magazine, the opening through which reinforcements could be delivered, was situated 2.25 in. to the right of the lever. Depression of this 2 in. long horizontal bar, which is the response selected for reinforcement, set the automatic scheduling and the recording apparatus into operation. When the required number of bar preses was completed a buzzer sounded and the reinforcement, which was .01 c.c. of water, was presented for 2 sec. in the dipper through the adjacent magazine. The animal chamber was placed within a larger ventilated light tight box which was insulated to reduce extraneous sounds. The continuous soft droning of the ventilating motor helped to further mask extraneous noises. The animal's daily performance was recorded on a cumulative graphic recorder. Pause measures were taken independently on an electronic timer measuring in 1/100 minutes.

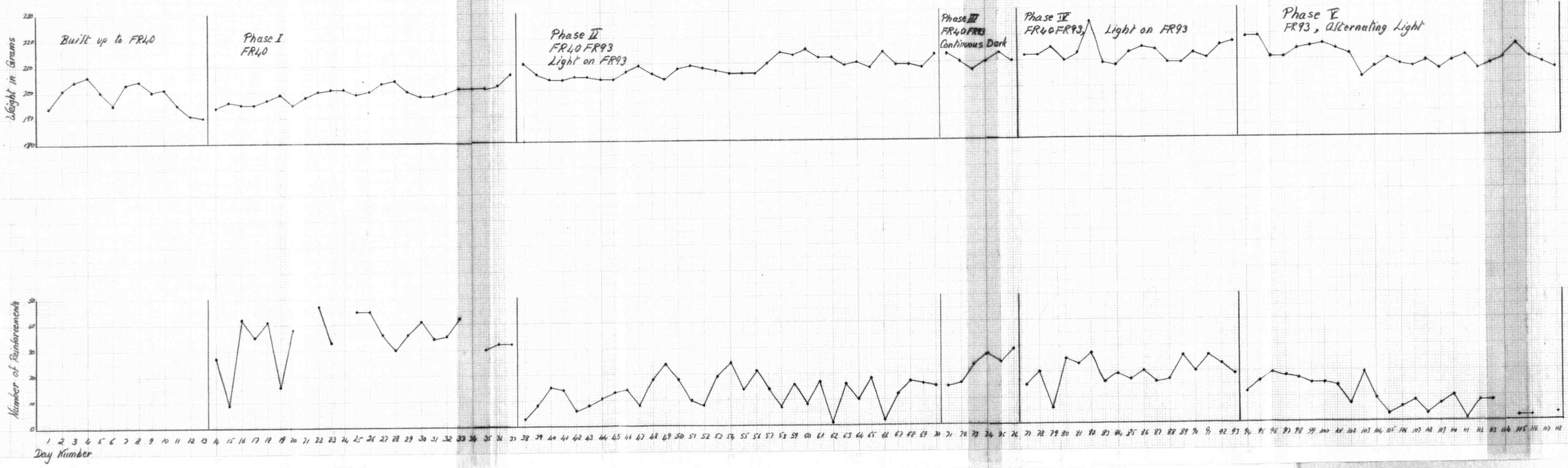
3. Procedure

The basic procedure adopted to answer the main question posed in this thesis was to reinforce the animals on a simple FR schedule until the lengths of the pauses became relatively stable, thenceforward to shift them to a <u>mult</u> FRFR where the original fixed ratio would form the first component of the schedule and a novel fixed ratio, of a greater magnitude, would be added as the second component to be alternated with the first one regularly. Figuratively, the multiple schedule was essentially of the form FRxFRy, where x represented the original shorter value, and y, the new larger value. That was the procedure in its general form as followed with all of the animals. Following is the procedure in detail described separately for each individual animal, with supplementary figures; 1, 2, 3, 4 for Rats S3, S13, S2, and S14, respectively. In the figures are plotted the total number of reinforcements - as counted from the cumulative graphic records - made by the animal daily, and the corresponding weight. (Gaps in the reinforcement curves show the days that are missed. The animal's weight was taken anyway).

a) Rat S3, had had previous training on operant conditioning and was 226 days old when the experiment began. The animal was given reinforcement on a short fixed ratio schedule which was gradually increased in size until, by the end of the 13th session, FR40 was reached. It was decided to stabilize the rat at this ratio, and so the preliminary training stage was over and the first formal phase of the experiment began on Day 14. In

Phase I the animal was reinforced for 21 daily ½ hour sessions on FR40. Pause measures were taken for all 21 sessions, and the median pauses after odd and even reinforcements were computed separately. In

Phase II the schedule was changed to mult FR40FR93 where a red and a green light were correlated with the larger of the two fixed ratios. The lights came on immediately the reinforcement following the completion of 40 responses was presented, and remained on until the next reinforcement was delivered. The animal was run on this schedule for 33 daily sessions. Pause measures, however, were not taken until the 13th day. (It was believed unnecessary to do otherwise as the animal, during the early days of this phase, was in the



Built up to FR40
Phase I
FR40
Phase II
FR40 FR93
Light on FR93
Phase III
FR40 FR93
Continuous Dark
Phase IV
FR40 FR93, Light on FR93
Phase V
FR93, Alternating Light
Weight in Grams
230
220
210
200
190
180
Number of Reinforcements
50
40
30
20
10
0
Day Number
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118

process of adjusting to the new schedule). The median pauses after the short and long runs were computed separately. In

Phase III the light was no longer paired with the FR93 component; and the schedule became essentially mix FR40FR93. The animal was reinforced for 6 daily ½ hour sessions on this schedule. Pause measures were taken on all 6 sessions, and the median pauses after the short and long runs were computed separately. In

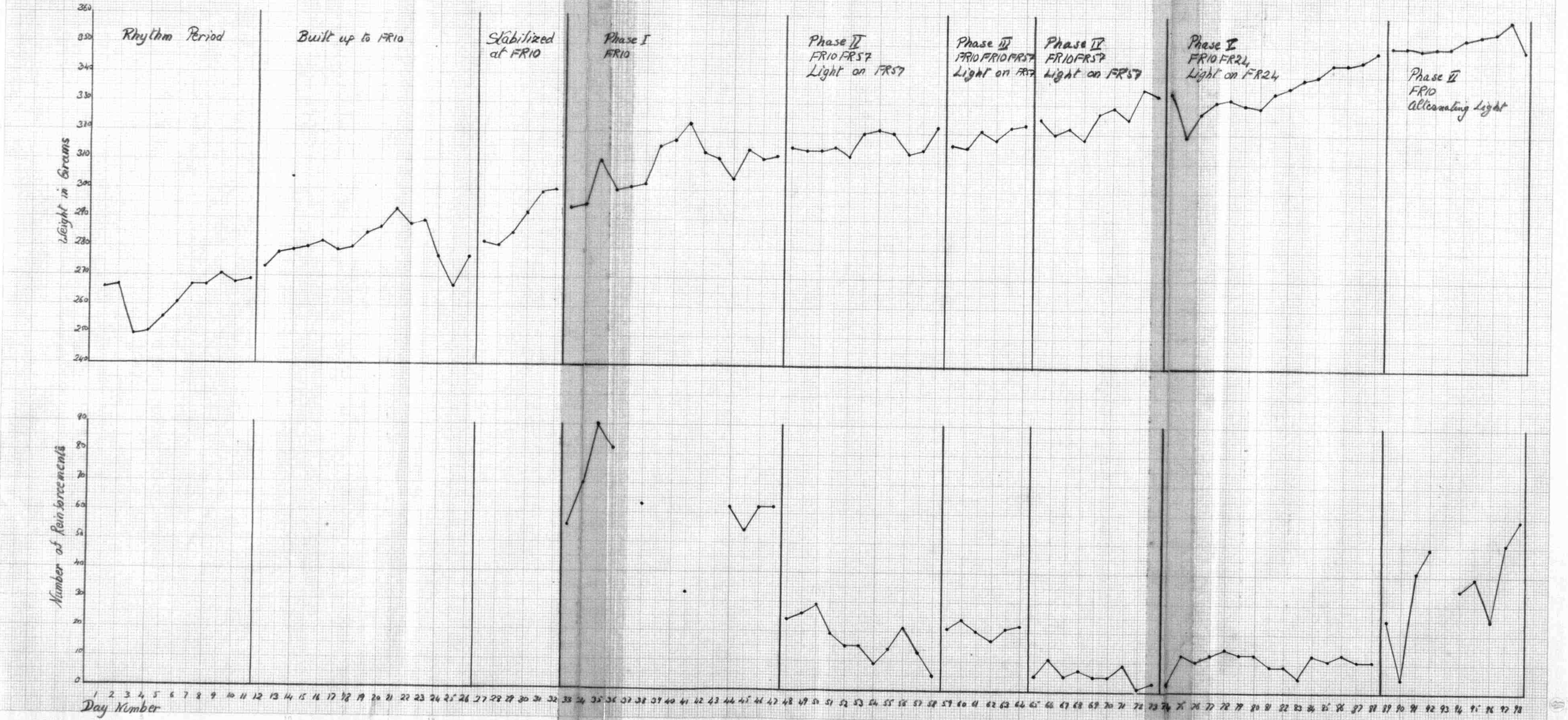
Phase IV the light was restored to the FR93 component; and hence the schedule was the same as it was in Phase II . (This was done to test further the effect of the light). The duration of this phase was limited to 17 days. In

Phase V the animal was replaced on a simple FR schedule, this time of the value 93. Light was made to alternate with every other run, and the median pauses after the runs in the dark (actually in the faint normal light) and the runs in the light were computed separately. The animal was run on this schedule for a total of 23 sessions, of which the last 13 show rather poor overall responding. By the end of this phase the experiment was terminated. Rat S3 had been used for a total of 118 days.

b) Rat S13 was 88 days old at the beginning of the experiment. Having had no previous training in conditioning of any sort it was started on a water regimen under which it was only given water for one half hour daily. The rat was fed ad libitum. This adaptation period lasted for 11 days, after which conditioning began. After

Rat S 13

Fig. 2.


Rhythm Period
Built up to FR10
Stabilized at FR10
Phase I FR10
Phase II FR10 FR57 Light on FR57
Phase III FR10 FR10 FR57 Light on FR57
Phase IV FR10 FR57 Light on FR57
Phase V FR10 FR24 Light on FR24
Phase VI FR10 Alternating Light
Weight in Grams
360
350
340
330
320
310
300
290
280
270
260
250
240
Number of Reinforcements
90
80
70
60
50
40
30
20
10
0
Day Number
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

2 or 3 sessions on crf[x] the animal was placed under a very short fixed ratio schedule which was gradually increased in size until, by the 15th session, FR10 was reached. This rat was rather slow in its behaviour so it was decided to stabilize it at this fixed ratio, building it up no further. After 6 such sessions of reinforcement on FR10 the animal's performance was uniform enough for pause measures to be taken. Thus ended the preliminary training stage and the first formal phase of the experiment began on the 7th day since the placement of the animal on FR10. In

<u>Phase I</u> reinforcement on FR10 was continued for 10 more half hour sessions. Pause measures were taken, and the median pauses after odd and even reinforcements were computed separately. In

<u>Phase II</u> the schedule was changed to <u>mult</u> FR10FR57 where the red and green lights were correlated with the larger ratio. Pause measures were taken, and the median pauses after the short and long runs were computed separately. The animal was run on this schedule for 11 sessions during which no differential pausing resulted and the overall performance was rather poor. It was thus decided to increase the reinforcement density. Hence, in

<u>Phase III</u> the reinforcement was scheduled on repeating <u>mult</u> FR10FR10FR57, light still being correlated with FR57. The animal was run on this schedule for 6 sessions. Pause measures were taken for all 6 sessions, and the median pauses after the 'first' short runs, the 'second' short runs (which immediately precede the long

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[x] Continuous reinforcement

runs), and the long runs, were computed separately. Under this schedule the animal's overall performance improved and it was thus decided to replace it on mult FR10FR57. In

Phase IV the reinforcement was re-scheduled on mult FR10FR57. The animal's rate of responding deteriorated enough to necessitate another change in reinforcement density. This time it was decided to decrease the size of the larger fixed ratio. In

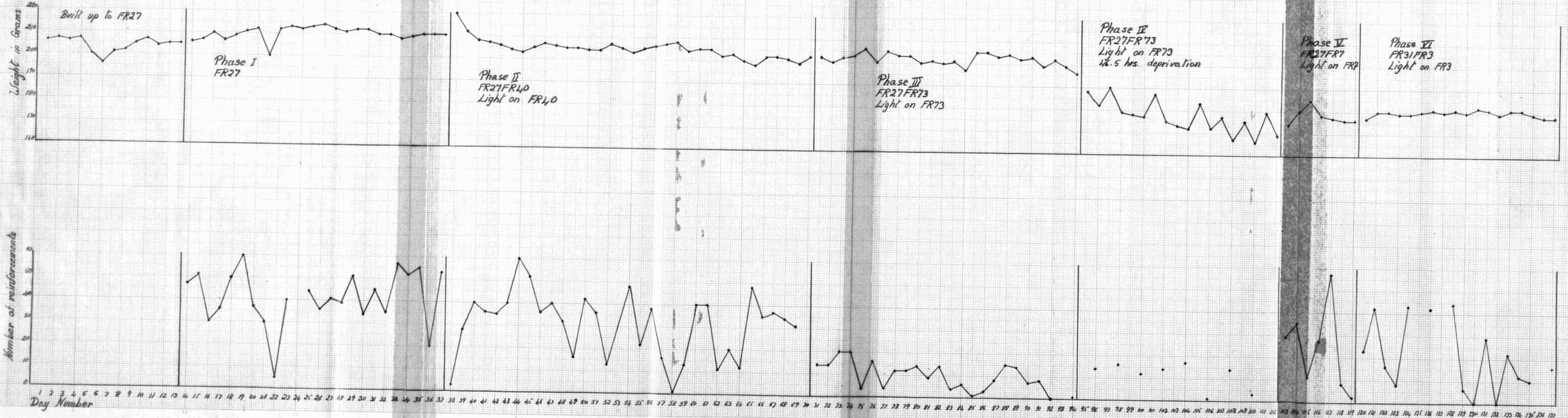
Phase V the rat was reinforced on mult FR10FR24 - light being paired with FR24. The subject remained on this schedule for 15 sessions. Pause measures were taken for all 15 sessions, and the median pauses after the short and long runs were computed separately. In

Phase VI the animal was replaced on simple FR10, this time with the light being paired with every other run. Median pauses after the runs in the dark and the runs in the light were computed separately. After 9 sessions of reinforcement on this schedule the experiment was terminated. Rat S13 had been used for a total of 98 days.

Rat S2, had had previous training with operant conditioning and was 226 days old when the experiment began. The animal was given reinforcement on a short fixed ratio schedule which was gradually increased in magnitude until, by the end of the 13th session, FR27 was reached. It was decided to stabilize the rat at this ratio, and so the preliminary training stage was over and the first formal

Rat S2

Fig.3.


Weight in Grams
220
210
200
190
180
170
160
Built up to FR27
Phase I
FR27
Phase II
FR27FR40
Light on FR40
Phase III
FR27FR73
Light on FR73
Phase IV
FR27FR73
Light on FR73
46.5 hrs. deprivation
Phase V
FR27FR7
Light on FR7
Phase VI
FR31FR3
Light on FR3
Number of reinforcements
60
50
40
30
20
10
0
Day Number

phase of the experiment began on Day 14. In

Phase I the animal was reinforced for 23 daily ½ hour sessions on FR27. Pause measures were taken for all 23 sessions, and the median pauses after odd and even reinforcements were computed separately. In

Phase II the schedule was changed to *mult* FR27FR40 where the red and green lights were correlated with the larger ratio. Pause measures were taken, and the median pauses after the short and long runs were computed separately. The animal was run on this schedule for 32 sessions during which no differential pausing resulted, though the overall performance was uniform and orderly. It was thus decided to increase the difference in size between the two fixed ratios as this would be more conducive to the development of discrimination. Hence, in

Phase III the reinforcement was scheduled on *mult* FR27FR73 - lights being on during FR73. The animal was run on this schedule for 23 sessions. Pause measures were taken for all 23 sessions, and the median pauses after the short and long runs were computed separately. Still no differential pausing resulted. However, the median pauses were based on very few measures as the animal's overall responding deteriorated markedly. It was thus decided to increase the drive. In

Phase IV the animal remained on *mult* FR27FR73. However, it was placed on a water-deprivation schedule of 46½ hours. Pause measures were taken for 8 sessions of reinforcement on this schedule, and the median pauses after the short and long runs were computed separately. Performance on this regime improved. This however was not true of the last few sessions where the animal hardly responded. It was thus decided to increase the reinforcement density. In

Phase V the schedule was mult FR27FR7.[x] Here, the light was correlated with the shorter of the fixed ratios; the FR7 component. This was done because the FR27 component had always been correlated with 'darkness', and a change at this stage of the experiment was believed undesirable. Median pauses after the short and long runs were computed separately. Under this schedule the animal's overall performance improved. However, differential pausing was lost, and it was decided by the end of the 6th session again to increase the difference in ratio size between the two components of the multiple schedule. As it was the intention to keep the reinforcement density constant both of the FR components had to be broken up in value. In

Phase VI the FR27 component was raised to 31, and the FR7 lowered to 3. The schedule became mult FR31FR3, and lights remained on during the shorter ratio. Median pauses after the short and long runs were computed separately. After 15 sessions of reinforcement on this schedule the experiment was terminated. Rat S2 had been used for a total of 137 days.

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[x] The motivation was reduced to 22½ hrs. water-deprivation from this point onwards.

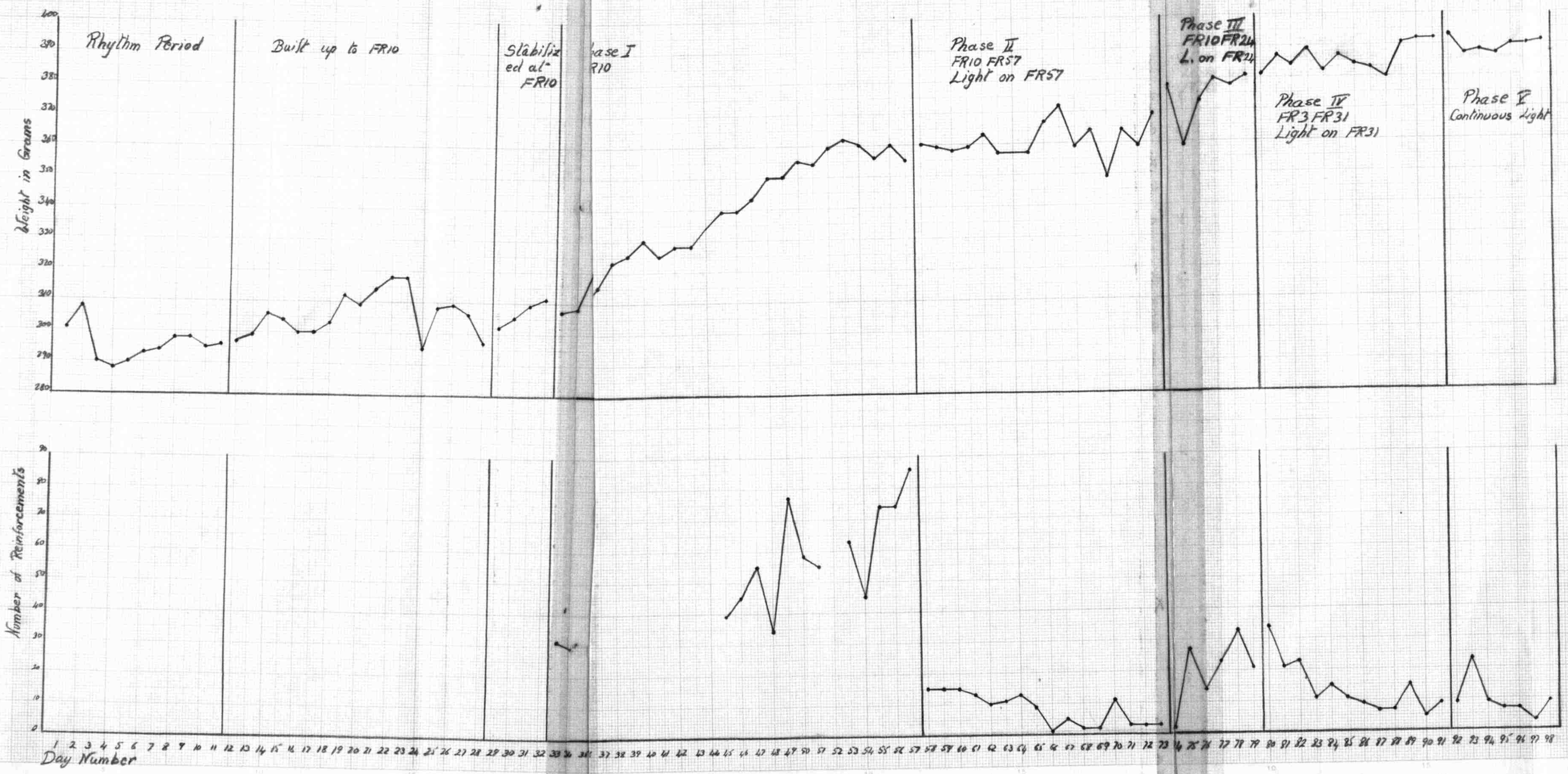
Rat S14 was 88 days old at the beginning of the experiment. Having had no previous training in conditioning of any sort it was started on a water regimen under which it was only given water for one half hour daily. The rat was fed *ad libitum*. This adaptation period lasted for 11 days, after which conditioning began. After 2 or 3 sessions on crf the animal was placed under a very short fixed ratio schedule which was gradually increased in size until, by the end of the 17th session, FR10 was reached. The rat was rather slow in its behaviour so it was decided to stabilize it at this fixed ratio. After 4 sessions of reinforcement on FR10 the animal's performance was orderly enough for pause measures to be taken. Thus ended the preliminary training stage and the first formal phase of the experiment began on the 5th day after the placement of the animal on FR10. In

Phase I reinforcement on FR10 was continued for 15 more half hour sessions. Pause measures were taken, and the median pauses after odd and even reinforcements were computed separately. In

Phase II the schedule was changed to *mult* FR10FR57 where the red and green lights were correlated with the larger ratio. Pause measures were taken, and the median pauses after the short and long runs were computed separately. The animal was run on this schedule for 16 sessions during which the overall rate of responding was poor. It was thus decided to increase the reinforcement density. Hence, in

Rat S14

Fig. 4.



Rhythm Period
Built up to FR10
Stabilized at FR10
Phase I FR10
Phase II FR10 FR57 Light on FR57
Phase III FR10 FR24 L. on FR24
Phase IV FR3 FR31 Light on FR31
Phase V Continuous Light
Weight in Grams
280
290
300
310
320
330
340
350
360
370
380
390
400
Number of Reinforcements
0
10
20
30
40
50
60
70
80
90
Day Number
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

Phase III the reinforcement was scheduled on mult FR10FR24, lights being paired with FR24. Median pauses after the short and long runs were computed separately. Under this schedule the animal's overall performance improved. However, differential pausing was lost, and, by the end of the 6th session, it was decided to increase the difference in ratio size keeping the reinforcement density constant. In

Phase IV the schedule was mult FR3FR31, lights being on during FR31. Median pauses after the short and long runs were computed separately. After 12 sessions of reinforcement on this schedule the lights were left on during both FR components. Hence, in

Phase V the schedule was essentially mix FR3FR31. The animal was reinforced for 7 daily ½ hour sessions on this schedule. Pause measures were taken on all 7 sessions, and the median pauses after the short and long runs were computed separately. With this phase the experiment ended. Rat S14 had been used for a total of 98 days.

In the next chapter the results of the experiment will be presented for each animal separately.

Chapter III

RESULTS

Rat S3 The results of this animal are presented in Fig.5. (opp. page 23). The figure shows separately, over the daily sessions, the median post-reinforcement pauses after each ratio. In

Phase I, on FR40, the median pauses after odd and even reinforcements are shown separately by 2 lines. As can clearly be seen from the graph the two median pause lines drawn overlap a great deal and proceed in a horizontal direction. The Wilcoxon matched-Pairs signed-Ranks Test[21] revealed no significant differences between the pauses after odd and even reinforcements, and the median of the median pauses - after both odd and even reinforcements - was 6.6 sec. In

Phase II reinforcement was scheduled on mult FR40FR93, and the 19 sessions under this schedule show distinct and systematic differences between the pauses after each of the two component fixed ratios, with longer median pauses following the longer ratios and shorter median pauses following the shorter ratios in 18 out of the 19 sessions ($p < .01$, Wilcoxon). The exception, however, was made earlier in the period when the animal could still have been adjusting to the new schedule. (It is to be remembered that pause measures were not taken during the early sessions on this schedule. The animal was allowed to stabilize). Following is an example,

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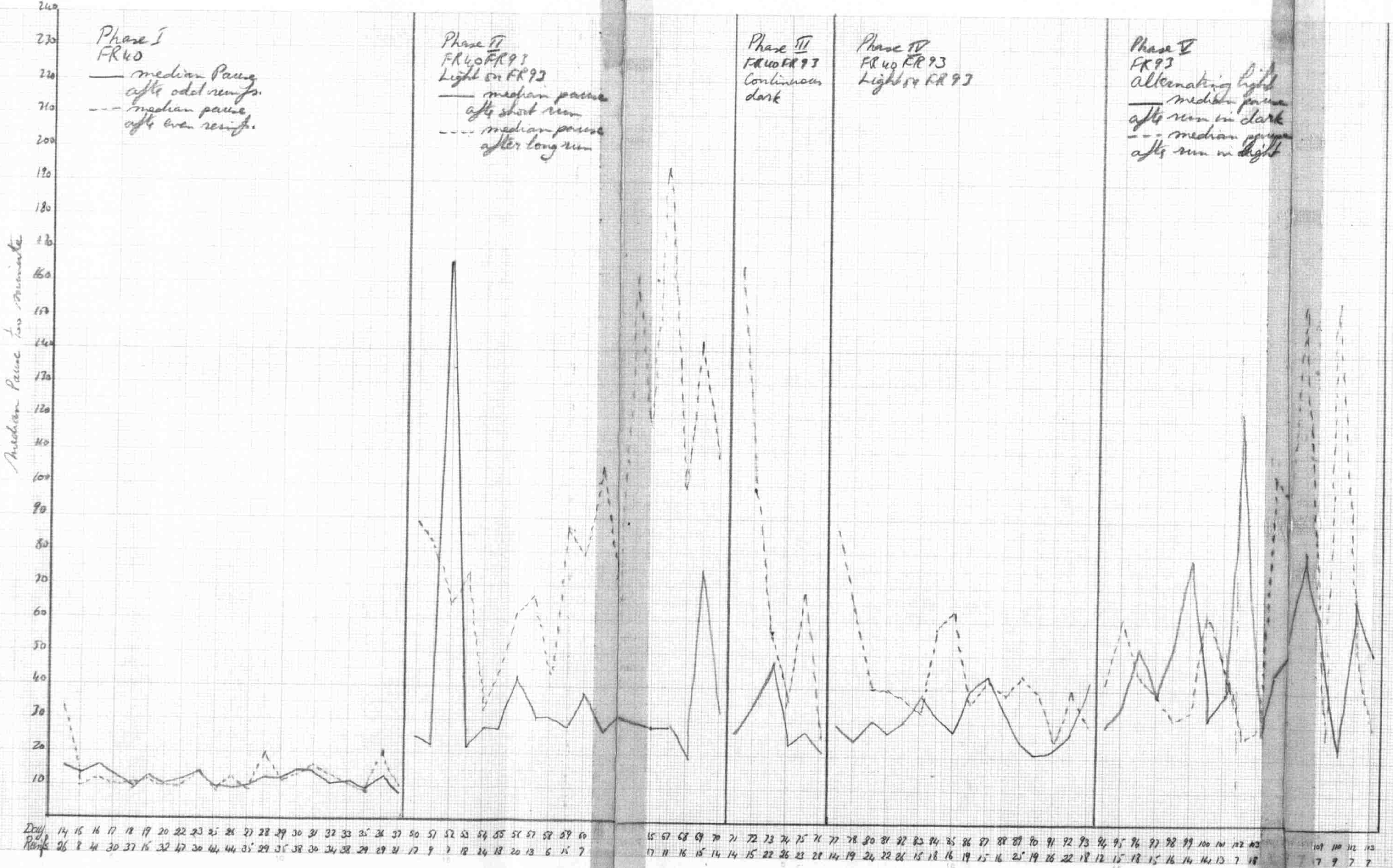
[21] Sidney, Siegel, Nonparametric Statistics, p. 75.

Rat S 3 Fig. 5.


Phase I
FR40
—— median Pause after odd reinfs.
- - - median pause after even reinfs.
Phase II
FR40 FR93
Light on FR93
—— median pause after short run
- - - - median pause after long run
Phase III
FR40 FR93
Continuous dark
Phase IV
FR40 FR93
Light on FR93
Phase V
FR93
alternating light
—— median pause after run in dark
- - - median pause after run in light
Median Pause in minute
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Day
Reinfs
14 16 16 17 18 19 20 22 23 25 26 27 28 29 30 31 32 33 35 36 37 50 51 52 53 54 55 56 57 58 59 60
26 8 41 30 37 15 32 47 30 44 44 35 29 35 38 30 34 38 29 29 31 17 9 7 18 24 18 20 13 6 15 7
65 67 68 69 70 71 72 73 74 75 76 77 78 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103
17 11 16 15 14 14 15 22 26 23 28 14 19 24 22 26 15 18 16 19 15 16 25 19 26 22 18 12 15 18 15 16 14 14 13 7 18
109 110 112 113
7 9 7 7

from the animal's cumulative graphic record, of performance on mult FR40FR93. It shows the 30th day of this schedule (Fig.6.). Note the short pauses after the short runs and the long pauses after the long runs.

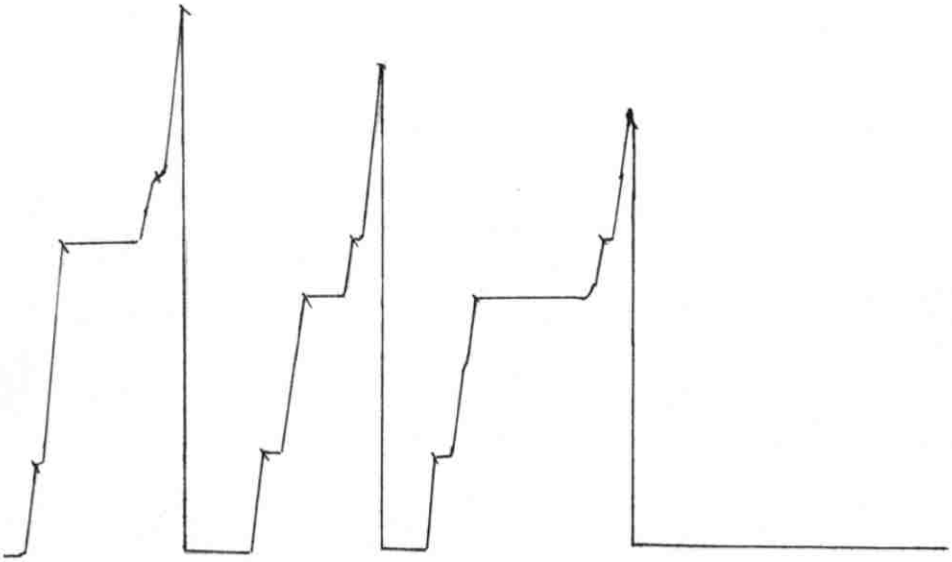


Fig.6. Thirtieth session on mult FR40FR93 (Rat S3)

Since in simple FR schedules long pauses have been shown to be correlated with large fixed ratios and short pauses with short fixed ratios it follows then that for this animal the length of the pause is controlled by the pre-reinforcement sequence of response. The following tentative conclusion is made;

Conclusion A Post-reinforcement pauses on fixed ratio schedules of reinforcement are determined (at least in part) by the magnitude of the response sequence prior to reinforcement.

Performance under <u>mult</u> FR40FR93, also, as compared with performance under FR40, shows that under the multiple schedule the median pause after the short fixed ratio has been extended (Fig.5. phases I & II; note the position of the solid line in phase II as compared with the intercrossing lines in phase I. The pattern is again horizontal; indicative of stability). The increase in pause length was from a median median of 6.6 sec., in the simple schedule, to a median median of 17.4 secs, in the multiple schedule. Since the size of the short fixed ratio remained unaltered in the two phases, then the increase in the length of the median pause after the short run in the multiple schedule must be due to the fact of the introduction of a new FR component into the schedule - new in the sense of having a different magnitude - and the inevitable change made in the reinforcement density; in this case, a reduction. A second conclusion then can be made;

<u>Conclusion B</u> <u>Post-reinforcement pauses on fixed ratio schedules of reinforcement are determined (at least in part) by the reinforcement density. The relationship between reinforcement density and pause length is an inverse relationship</u>.

<u>In phase III</u>, the removal of the light from the FR93 component of the multiple schedule resulted in a decrease in the length of the median pauses after the longer runs (Fig.5. phase III). The pauses did remain longer after the longer runs ($p < .05$. Wilcoxon), but they became short relative to what they were before. The dif-

ference in length was from a median median of 48.6 sec., in phase II, to a median median of 37.8 sec., in phase III. The median of the median pauses after the shorter runs (in phase III) was 16.35 sec. Since long pauses have previously occured in the dark the stimulus conditions effective during the pauses could not have controlled the length of the pause; otherwise, when darkness prevailed all the time, the pauses previously long should remain long, and the pauses previously short (which used to occur in the presence of light) should increase in length. It should then be the stimulus conditions effective during the pre-reinforcement run which determine (partially of course) the length of the pause. Darkness had previously controlled long pauses but short runs. When it prevailed all the time, previously long runs (which used to be followed by long pauses and occur themselves in the presence of light) should appear to, or be experienced by, the animal as though they were short runs _and be followed by short pauses_. The following conclusion then can be made.

Conclusion C _When a particular stimulus condition is made to prevail, for a considerable period of time, during a pre-reinforcement run which normally controls short pauses that stimulus continues to be effective in its control even when it is made to correlate with a pre-reinforcement run that normally controls long pauses_.

Though it refers to exteroceptive rather than interoceptive stimulation the above conclusion is consistent with conclusion A in the sense that it points to stimulus conditions <u>prior</u> to reinforcement as constituting the determinants of the post-reinforcement pause. The subsequent data in

<u>Phase IV</u> do not essentially support conclusion C. The light was restored to the FR93 component of the schedule and still the median pauses after the long runs remained at a relatively low level (Fig.5. phase IV). Not only that but some overlapping with the median pauses after the short runs occured. The difference between the median pauses after the short and long runs did remain significant ($p < .01$, Wilcoxon), but never were the big differences obtained earlier, in phase II, produced again. It is possible, however, that this might have happened if the animal had been further exposed to the schedule. The data in

<u>Phase V</u> were meant to test further conclusion B concerning reinforcement density. The light alternated with each FR93 run simply to cancel the effect of darkness vs. illumination, if any still existed. Median pauses after odd and even reinforcements, or after runs in dark and light, respectively, are shown separately in Fig.5. phase V. It is clear that the median pause lines drawn overlap a good deal and fluctuate very widely. The Wilcoxon test revealed no significant differences between the median pauses after odd and even reinforcements, and the median of the median pauses - after both odd and even reinforcements - was 28.8 sec. Under the multiple schedule in the preceding phase the median of the median

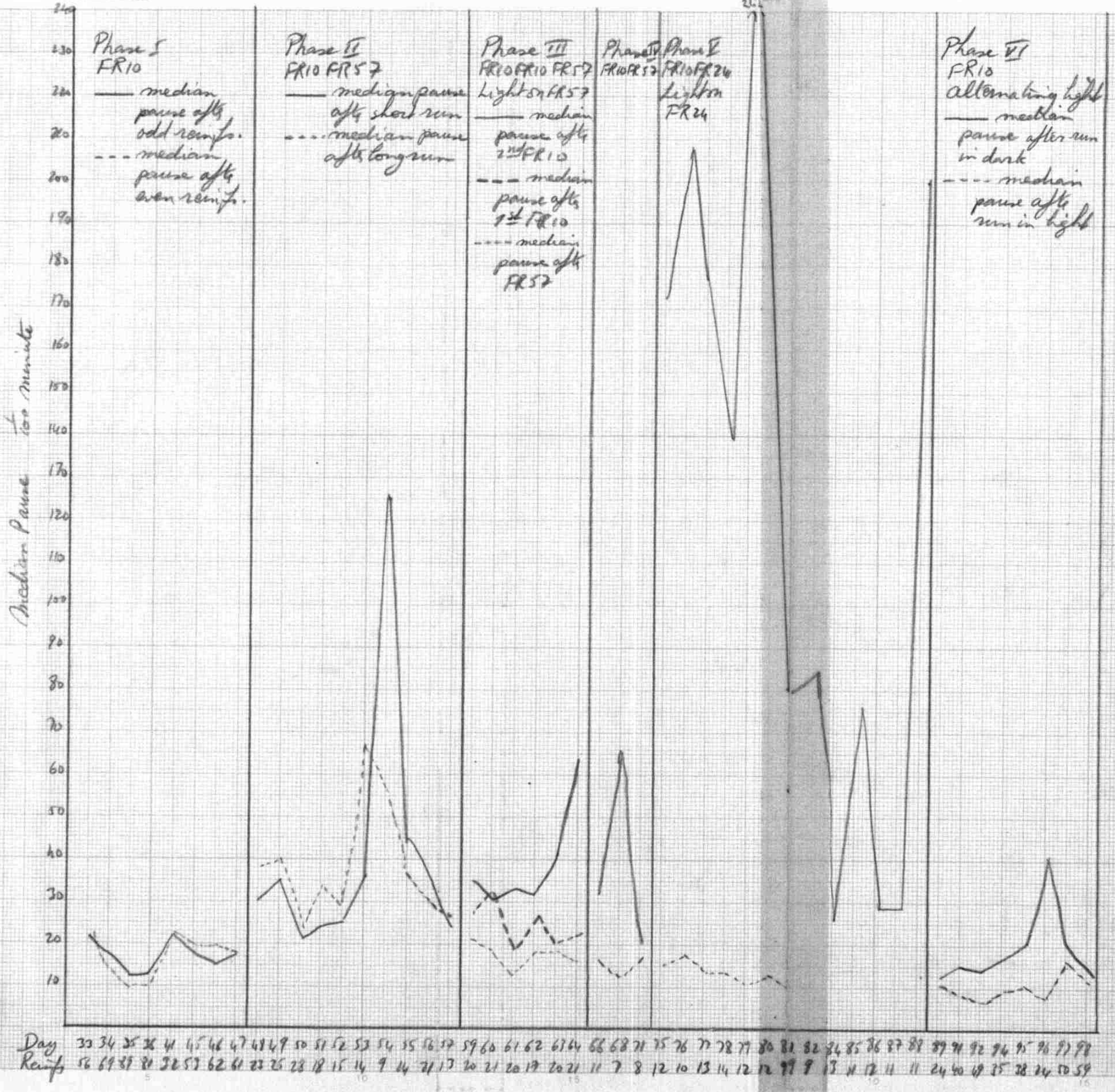
pauses after the FR93 ratio was 24.15 sec. - a smaller value. In phase V, then, with a decrease in reinforcement density the median pauses after the FR93 runs were extended. The finding supports conclusion B.

Rat S13 The results of this animal are presented in Fig.7. (opp. page 28). The figure shows separately, over the daily sessions, the median post-reinforcement pauses after each ratio. In

Phase I, on FR10, the median pauses after odd and even reinforcements are shown separately by 2 lines. As can clearly be seen from the graph the two median pause lines drawn overlap and proceed in a horizontal direction. The Wilcoxon Test revealed no significant differences between the pauses after odd and even reinforcements, and the median of the median pauses - after both odd and even reinforcements - was 10.2 sec. In

Phase II reinforcement was scheduled on *mult* FR10FR57, and the 10 sessions under this schedule show no differential pausing (Fig.7. phase II). The median pauses after the longer and shorter ratios overlap and, application of the Wilcoxon test revealed no significant difference between them. The change of the schedule from FR10 to *mult* FR10FR57 has again yielded an increase in the length of the median pause after the 10 ratio. The increase in length was from a median median of 10.2 sec., in the simple schedule, to a median median of 19.2 sec., in the multiple schedule. The finding supports conclusion B. Under this schedule the animal's over-

Rat S13 Fig. 7.


Median Pause 100 minute
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
262
Phase I
FR10
—— median pause after odd reinf.
- - - median pause after even reinf.
Phase II
FR10 FR57
—— median pause after short run
- - - - median pause after long run
Phase III
FR10 FR10 FR57
Light on FR57
—— median pause after 2nd FR10
— — — median pause after 1st FR10
- - - - median pause after FR57
Phase IV
FR10 FR57
Phase V
FR10 FR24
Light on FR24
Phase VI
FR10
alternating light
—— median pause after run in dark
- - - - median pause after run in light
Day 33 34 35 36 41 45 46 47 48 49 50 51 52 53 54 55 56 57 59 60 61 62 63 64 66 68 71 75 76 77 78 79 80 81 82 84 85 86 87 88 89 91 92 94 95 96 97 98
Reinf. 56 69 35 81 32 57 62 61 27 25 23 18 15 14 9 14 21 17 20 21 20 19 20 21 11 7 8 12 10 13 14 12 12 97 9 13 11 12 11 11 24 40 49 35 38 34 50 59

all rate of response was rather poor, and when in

Phase III the reinforcement was scheduled on *mult* FR10FR10 FR57 the rate of responding improved, and the 6 sessions under this schedule show distinct and systematic differences between the pauses after each of the three component fixed ratios; with *longer median pauses following the shorter ratios and shorter median pauses following the longer ratios* in all 6 sessions (p.<0.5, Wilcoxon), *and*, with longest median pauses following the second of the shorter fixed ratios (the one which immediately precedes the FR57 component) in 5 out of the 6 sessions, (Fig.7. phase III). The difference between the median pauses after the first and second FR10 components was shown, by application of the Wilcoxon Test, not to be significant, although it might have become so had more measures been taken. In

Phase IV the animal was replaced on *mult* FR10FR57 to obtain further data on this schedule. Differential pausing was maintained, the difference being in the same direction as it was in phase III (Fig.7. phase IV). The rate of responding, however, was again poor, and the schedule, in

Phase V, was changed to *mult* FR10FR24. This increase in reinforcement density yielded a much better rate of responding. Differential pausing was maintained all through the 13 sessions of reinforcement under this schedule (Fig.7. Phase V). Again the pauses were longer after the *short* runs and shorter after the *long* runs (p$<.01$ Wilcoxon). Following is an example, from the animal's cumulative record of performance on <u>mult</u> FR10FR24. It shows the 13th day of this schedule (Fig.8.). Note the short pauses after the long runs and the long pauses after the short runs. Note also how the reinforcements come in pairs.

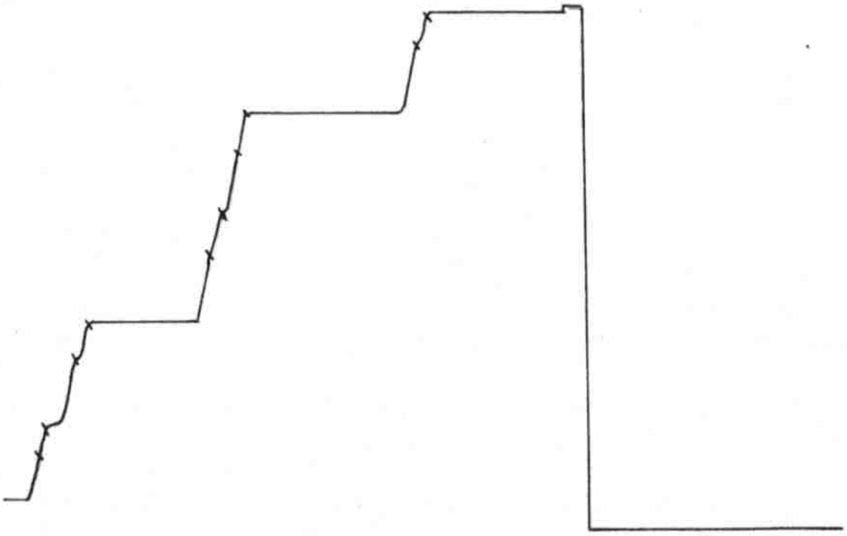


Fig.8. Thirteenth session on <u>mult</u> FR10FR24 (Rat S13)

The findings for this animal, viewed independently, would lead to the conclusion that the post-reinforcement pauses on FR schedules are determined by the post-reinforcement run. This conclusion is a direct contradiction of conclusion A. However, an examination of the multiple schedules under which those two animals were placed; essentially, of the magnitudes of the component fixed ratios, makes it possible to reconcile the data.

For Rat S3 reinforcement was scheduled on <u>mult</u> FR40FR93. The animal, after making 93 bar presses and obtaining water, had to make another 40 responses (a number which is rather large in itself) to procure another reinforcement. For Rat S13, on the other hand, reinforcement was scheduled on *mult* FR10FR57, and *mult* FR10 FR24. The animal, after running the long ratio on either schedule, had to make only 10 more responses (a number which is rather small in itself) to procure another reinforcement. Hence, a short pause following the long run seems to be reasonable. The following conclusion is possible;

Conclusion D *There is a certain threshold level of the shorter of the two FR components of a mult FRFR schedule above which pauses are shorter after the short runs and longer after the long runs, and below which pauses are shorter after the long runs and longer after the short runs*.

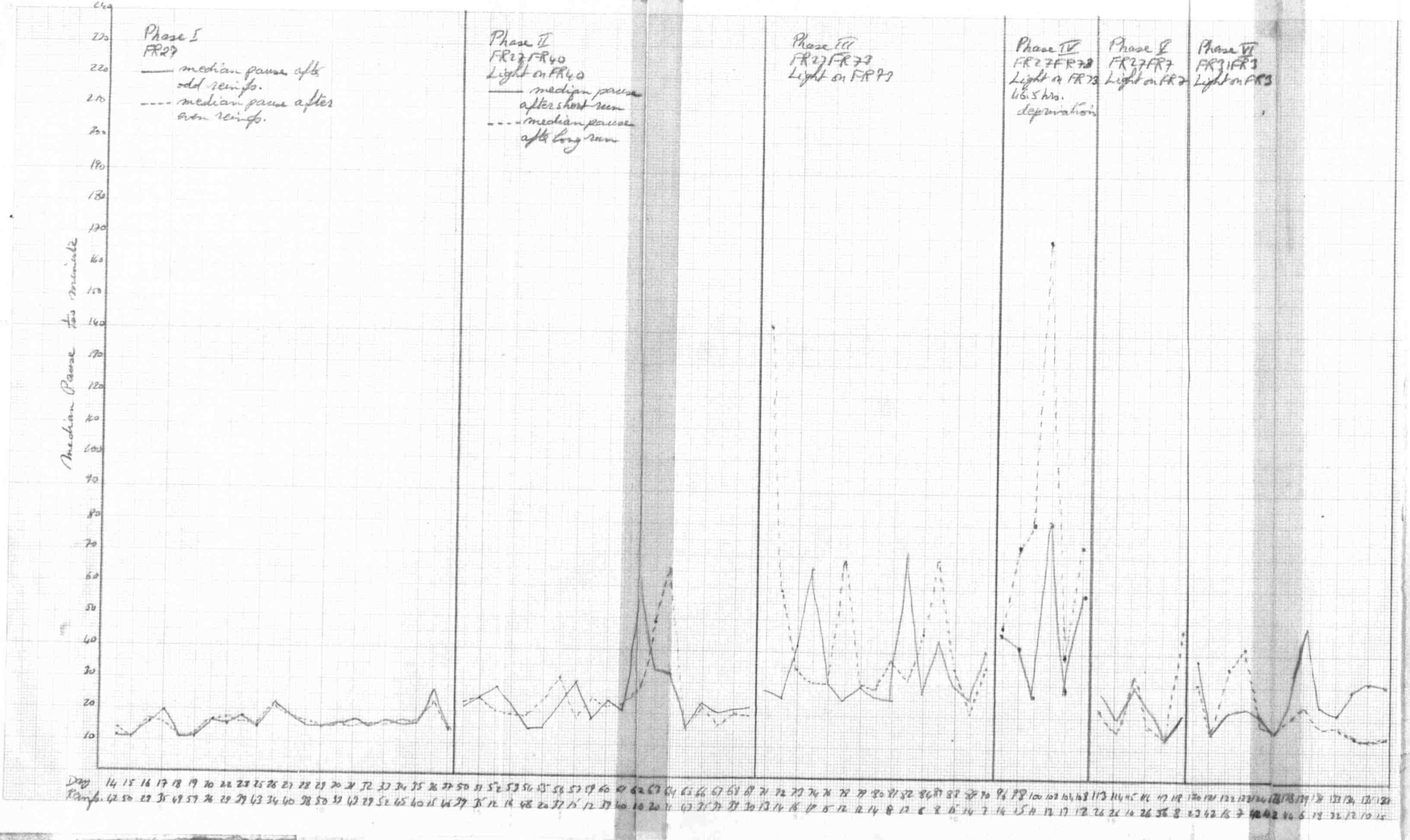
The conclusion of course is *ad hoc* for the moment. The data in

Phase VI was meant to test the effect of the light. The animal was reinforced on simple FR10, and the light was correlated with every other run. All 8 sessions under this schedule show distinct and systematic differences between the pauses after the runs in the dark and the pauses after the runs in the light ($p < .01$, Wilcoxon), with longer median pauses following the runs in the dark and shorter median pauses following the runs in the light (Fig.7. phase VI). The results support conclusion C but only in the sense that the light does enter into the control of the post-reinforcement pause (otherwise, the median pause lines would have overlapped, the magnitude of the fixed ratio being the same). It is not possible from the data in phase VI for this animal to tell whether the post-reinforcement pause was controlled by the stimulus conditions effective during the pauses or the stimulus conditions effective during the pre-reinforcement runs. In phase V rat S13 was making longer pauses after the darkened-short runs and shorter pauses after the illuminated-long runs. In phase VI, then, the animal could be making longer pauses after the darkened runs either because of the fact that darkened runs had previously controlled long pauses, or because of the fact that they, the pauses, were themselves occurring in the presence of light, and light had previously been associated with long pauses.

Rat S2 The results of this animal are presented in Fig.9. (opp. page 32). The figure shows separately over the daily sessions the median post-reinforcement pauses after each ratio run. In

Phase I, on FR27, the median pauses after odd and even reinforcements are shown separately by 2 lines. As can be seen from the graph the two median pause lines drawn overlap a great deal and proceed in a horizontal direction. The Wilcoxon test revealed no significant differences between the pauses after odd and even reinforcements, and the median of the median pauses - after both

Rats2 Fig. 9.


Median Pause in minute
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Phase I
FR27
—— median pause after odd reinfs.
---- median pause after even reinfs.
Phase II
FR27FR40
Light on FR40
—— median pause after short run
---- median pause after long run
Phase III
FR27FR79
Light on FR79
Phase IV
FR27FR78
Light on FR78
46.5 hrs. deprivation
Phase V
FR27FR7
Light on FR7
Phase VI
FR3FR3
Light on FR3
Day 14 15 16 17 18 19 20 22 23 25 26 27 28 29 30 31 32 33 34 35 36 37 50 51 52 53 54 55 56 57 59 60 61 62 63 64 65 66 67 68 69 71 72 73 74 76 78 79 80 81 82 84 87 88 89 90 96 98 100 102 104 108 113 114 115 116 117 118 120 121 122 123 124 128 129 130 133 134 135 136
Reinfs. 42 50 29 35 49 59 26 29 39 43 34 40 38 50 32 43 29 52 45 40 15 46 39 35 12 16 48 20 37 15 12 39 40 10 20 11 43 31 37 39 30 13 14 16 19 15 12 12 14 8 12 6 8 15 14 7 14 15 11 12 17 12 26 26 10 26 56 8 23 43 15 7 42 42 44 6 18 32 12 10 15

odd and even reinforcements - was 9.6 sec. In

Phase II reinforcement was scheduled on mult FR27FR40, and the 19 sessions under this schedule show no differential pausing (Fig.9. phase II). The median pauses after the longer and shorter ratios overlap, and application of the Wilcoxon test revealed no significant difference between them. The change of the schedule from FR27 to mult FR27FR40, however, resulted in an increase in the length of the median pause after the 27 ratio run. The increase in length was from a median median of 9.6 sec., in the simple schedule, to a median median of 13.8 sec., in the multiple schedule. The finding supports conclusion B. In

Phase III reinforcement was scheduled on mult FR27FR73. Still, no differential pausing developed (Fig.9. phase III). The median pause lines drawn overlap a great deal, and application of the Wilcoxon test revealed no significant difference. However, the overall responding of the animal was rather poor and the daily medians computed were based on very few pause measures. The change to mult FR27FR73, however, resulted in a further increase in the length of the median pause after the 27 ratio run, up to a median median of

18.3 sec. This progressive increase in the length of the pause after the fixed ratio run with the progressive decrease in the reinforcement density is a further confirmation of conclusion B. In

Phase IV, under a 46½ hrs. water deprivation regime the animal's overall responding improved, and, the 6 sessions on mult FR27 FR73 show distinct and systematic differences between the pauses after each of the two component fixed ratios (Fig.9. phase IV), with longer median pauses following the longer ratios and shorter median pauses following the shorter ratios in all of the sessions ($p < .05$, Wilcoxon). Following is an example, from the animal's cumulative records, of performance on mult FR27FR73. It shows the 4th day of this schedule (Fig.10.). Note the short pauses after the short runs and the long pauses after the long runs.

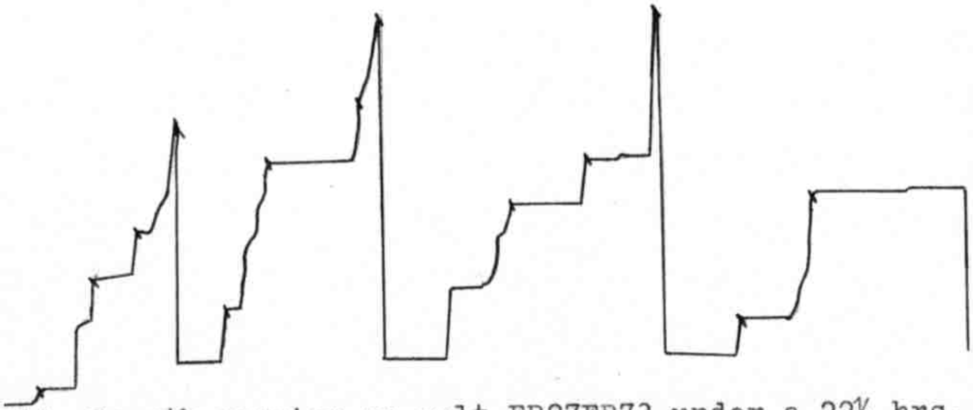


Fig. 10. Fourth session on mult FR27FR73 under a 22½ hrs. water-deprivation regime (Rat S2)

For this animal then the length of the pause is controlled by the pre-reinforcement sequence of response. This is consistent with conclusion A. In

Phase V, the 6 sessions on *mult* FR27FR7 show no differential pausing (Fig.9. phase V). However, the median pause after the 27 ratio run has decreased in length to a median median of 12.9 sec. This is consistent with conclusion B. In

Phase VI reinforcement was scheduled on *mult* FR31FR3. Under this schedule the animal made shorter pauses after the shorter runs and longer pauses after the longer runs only in 3 out of 13 sessions. In 1 session the median pauses after the short and long runs coincided, and in 9 out of the 13 sessions the median pauses were *shorter* after the *longer* runs and *longer* after the *shorter* runs (Fig.9. phase VI). When all the pairs of pauses after a long and a short run in the present phase VI (reinforcement on *mult* FR31FR3) were compared with all the pairs of pauses after a long and a short run in phase IV (reinforcement on *mult* FR27FR73, under a 22½ hrs. water-deprivation regime) it was found that in phase VI the majority of the shorter pauses followed the longer runs while, in phase IV, the majority of the shorter pauses followed the shorter runs ($x^2 = 24.55$, p. .001,df1). This then is confirmation of conclusion D. However, application of the Wilcoxon test to all the data in phase VI did not show a significant difference between the pauses after the long and the short runs. However, on all the final 7 sessions the pause following the shorter run is longer than that following the longer run, and this difference is significant ($p < .05$, Wilcoxon).

Following is an example, from the animal's cumulative records, of performance on *mult* FR31FR3. It shows the 13th day of this schedule (Fig. 11.). Note the short pauses after the long runs and the long pauses after the short runs. The figure may be compared with Fig.10. on page 33. When for this animal reinforcement

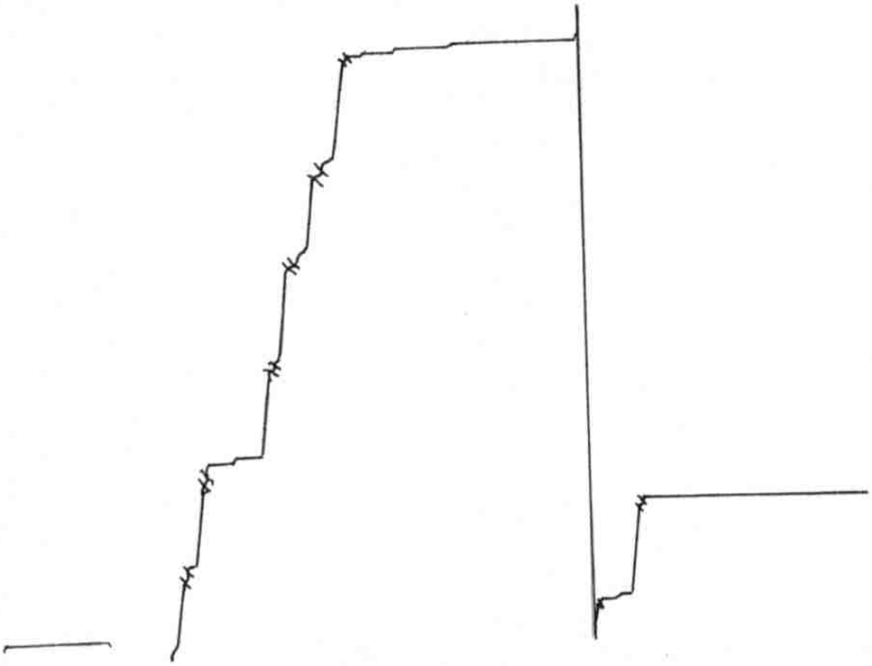


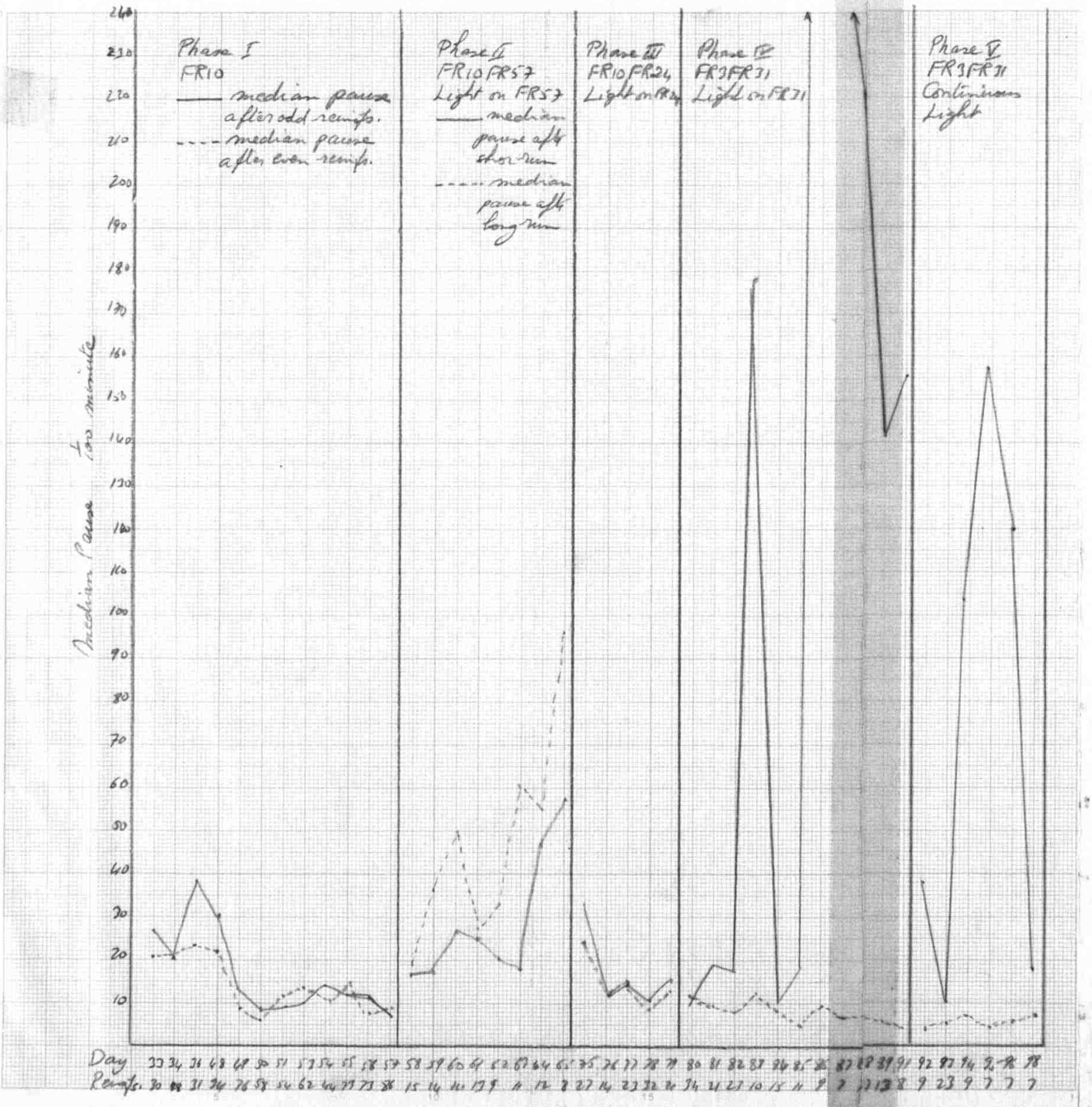
Fig. 11. Thirteenth session on mult FR31FR3 (Rat S2)

was scheduled on mult FR27FR73 the median pauses were shorter after the shorter runs and longer after the longer runs, when, on the other hand, reinforcement was scheduled on mult FR31FR3; with the magnitude of the short fixed ratio component made very much shorter the reverse was true.

Rat S14 The results of this animal are presented in Fig.12. (opp. page 36). The figure shows separately over the daily sessions the median post-reinforcement pauses after each ratio run. In

Phase I, on FR10, the median pauses after odd and even rein-

Rat S14 Fig. 12.



forcements are shown separately by 2 lines. As can be seen from the graph the two median pause lines drawn overlap a great deal and proceed in a horizontal direction. The Wilcoxon test revealed no significant difference between the pauses after odd and even reinforcements, and the median of the median pauses - after both odd and even reinforcements - was 7.35 sec. In

Phase II reinforcement was scheduled on *mult* FR10FR57, and the 8 sessions under this schedule show distinct and systematic differences between the pauses after each of the two component fixed ratios (Fig.12. phase II), with longer median pauses following the longer ratios and shorter median pauses following the shorter ratios in all of the sessions ($p < .01$, Wilcoxon). This is consistent with conclusion A. Also, performance under *mult* FR10FR57, as compared with performance under FR10, shows that under the multiple schedule the median pause after the short fixed ratio has been extended. The increase in length was from a median median of 7.35 sec., in the simple schedule, to a median median of 13.3 sec., in the multiple schedule. This change in the length of the pause as a function of a change in reinforcement density is consistent with conclusion B. In

Phase III, the 5 sessions on *mult* FR10FR24 show no differential pausing (Fig.12. phase III). However, the median pauses after the 10 ratio run have decreased in length to a median median of 8.1 sec. This is consistent with conclusion B. In

Phase IV the reinforcement density was kept constant but the schedule was changed to *mult* FR3FR31. Under this schedule only in 1 out of 11 sessions was the median pause shorter after the short run and longer after the long run. In all other 10 sessions, the median pauses were shorter after the longer runs and longer after the shorter runs (Fig.12. phase IV). The Wilcoxon test showed significance beyond the .01 level. When all the pairs of pauses after a long and a short run in the present phase IV (Reinforcement on *mult* FR3FR31) were compared with all the pairs of pauses after a long and a short run in phase II (reinforcement on *mult* FR10FR57) it was found that in phase IV the majority of the shorter pauses followed the longer runs while, in phase II, the majority of the shorter pauses followed the shorter runs ($x^2 = 9.66$, $p < .01$ dfl). These data are again confirmation of conclusion D. A reduction in the magnitude of the shorter of the fixed ratios on a multiple schedule to a very low value resulted in reverse behaviour on the part of the animal. Following is an example, from the animal's cumulative records, of performance on *mult* FR31FR3. It shows the 11th day of this schedule (Fig.13.). Note the short pauses after the long runs and the long pauses after the short runs. The figure illustrates also how reinforcements are taken in pairs.

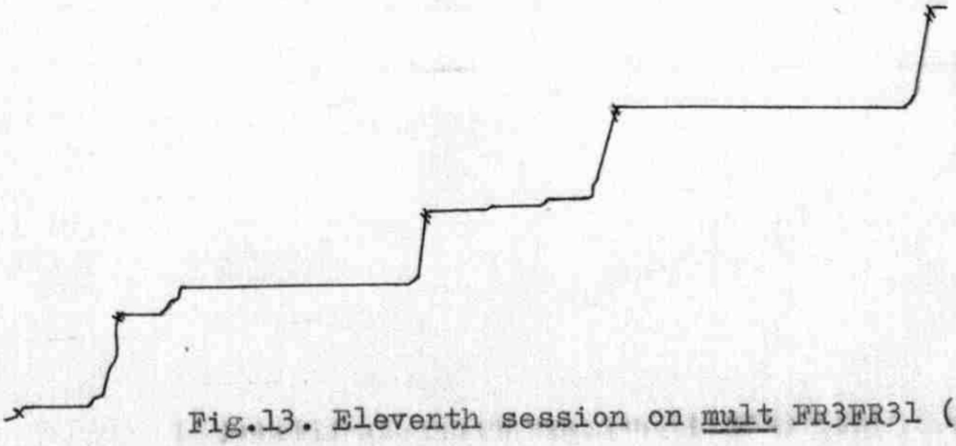


Fig.13. Eleventh session on *mult* FR3FR31 (Rat S14)

In phase V the correlation of the light with both components of the multiple schedule resulted in a decrease in the length of the median pause after the shorter run (Fig.12. phase V). The pauses did remain longer after the shorter runs ($p < .05$, Wilcoxon), but they became short relative to what they were before. The difference in length was from a median median of 84.6 sec., in phase IV, to a median median of 42.3 sec. in phase V. The schedule for this animal had been actually mult FR3 (in dark) FR31 (in light). Since long pauses previously occurred in the light the stimulus conditions effective during the pauses could not have controlled the length of the pause; otherwise, when light prevailed on both ratios, the pauses previously long would have remained long, and the pauses previously short (which used to occur in the presence of light) would have increased in length. It should then be the stimulus conditions effective during the pre-reinforcement run which have determined the length of the pause. Light had previously controlled also long runs. When it prevailed all the time, previously short runs should have been experienced by the animal as though they had been long runs and be followed by short pauses, (for this animal was making shorter pauses after the longer runs and longer pauses after the shorter runs in the phase immediately preceding phase V). The data in phase V, thus, confirm conclusion C.

Chapter IV

DISCUSSION

It was shown in the first chapter that the post-reinforcement pause is explained mainly in terms of the behaviour which precedes it. The results of the present study are consistent with this *general* point of view, but show further that, *under certain conditions, the control of the pause is not confined exclusively to the stimulus conditions prevalent at the beginning of the pause*. *In cases where the shorter of the FR components of a multiple schedule falls below a certain threshold level the pause is controlled by both the pre- and post-reinforcement runs jointly*. This latter finding is definitely inconsistent with Hull's specific concept of reactive inhibition - in which is implicit an explanation of pause lengths. For, if longer runs in ratio schedules give rise to more reactive inhibition and, consequently, require longer pauses for this negative drive to dissipate, how then could it be possible that, under certain conditions, longer pauses follow the shorter runs and shorter pauses follow the longer runs? The experiment has proved that the component fixed ratios of a multiple schedule of reinforcement *can* be manipulated in such a way so that longer pauses follow shorter runs and shorter pauses follow longer runs. It is possible, for example, to decrease the length of the long pause that normally follows a long ratio run simply by making the long fixed ratio alternate with a very short fixed ratio.

It is important, however, that the statement 'post-reinforcement pauses are, under certain conditions, controlled by the post reinforcement sequences of response' be not understood as meaning that pauses are sometimes determined by future events. The pauses are in fact determined by the preceding pattern of ratio runs. With repeated trials the animal has come to discriminate the schedule as a whole, and has learnt that after a long run only a few more responses are required to procure a second reinforcement.

SUMMARY

On FR schedules of reinforcement animals typically respond up to reinforcement and then pause. These post-reinforcement pauses have been explained both in terms of the behaviour which precedes them and that which follows them. The present thesis tests the relative effects of pre- and post-pause behaviour on the length of the pause.

The basic procedure adopted was to reinforce animals on simple FR schedules until the length of the pauses became relatively stable. Thereafter they were shifted to <u>mult</u> FRFR where the original fixed ratio formed the first component of the schedule, and a novel fixed ratio, of a greater magnitude, was added as the second component and alternated with the first one regularly.

The results showed that there is a certain threshold level of the shorter of the two FR components of a <u>mult</u> FRFR schedule above which pauses are shorter after the short runs and longer after the long runs, and below which pauses are shorter after the long runs and longer after the short runs. Hence, under certain conditions, the post-reinforcement run does enter into the control of the post-reinforcement pause, not teleologically, but because the animals were able to discriminate the schedule as a whole. That is, on a schedule of FR3FR31, for example, short pauses occurred after the FR31 segment indicating that the pause

was under the control not only of the preceding FR31 but of the FR3 that preceded that. In other words, the animal behaved as if it knew that after a long run a second reinforcement would quickly be given.

The findings are not necessarily inconsistent with prevalent views, but they add further information on the problem of pause-determination.

Post-reinforcement pauses were also found to be a function of reinforcement density.

Stimuli correlated with the behaviour that produced reinforcement, such as light, were also found to be effective in the control of the pause.

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