

ON SOME DETERMINANTS OF BEHAVIORAL CONTRAST

A Thesis

Presented to

The Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

Donald M. Wilkie

October, 1970



ACKNOWLEDGEMENTS

I wish to thank the members of my committee, Dr. M. F. Halasz and Mr. G. L. Martin, and especially my advisor, Dr. J. J. Pear, for their comments and assistance. I wish also to thank Bill Stevens for his assistance in running the subjects and my wife, Carol, for her assistance in typing the manuscript.

This investigation was supported by a National Research Council of Canada grant (APA7461) to Dr. J. J. Pear. The research reported here was conducted while the author was supported by a National Research Council of Canada Post-graduate Scholarship.

TABLE OF CONTENTS

Chapter		Page
I	Introduction	1
	1. Behavioral contrast.	1
	2. The determinants of behavioral contrast. ...	3
	3. Purpose of the present research: an investigation of the conditions responsible for behavioral contrast.	11
II	Some experiments with variable-time schedules	12
	1. Experiment I. Variable-time reinforcement in a multiple schedule.	12
	2. Experiment II. Variable-time reinforcement in a concurrent schedule.	29
	3. Summary.	40
III	Some experiments involving delayed reinforcement ..	41
	1. Experiment III. Delayed reinforcement in a multiple schedule.	41
	2. Experiment IV. A second experiment with delayed reinforcement in a multiple schedule.	50
	3. Experiment V. A third experiment with delayed reinforcement in a multiple schedule.	62
	4. Summary.	72
IV	Discussion	73
	1. The necessary and sufficient conditions for the occurrence of behavioral contrast. ...	73
	2. Some considerations concerning the definition of behavioral contrast.	76
	References	79
	Appendix	82

LIST OF TABLES

Table		Page
1.	Summary of Procedure.	16
2.	Summary of Procedure: Concurrent Schedules.	34
3.	Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule.	44
4.	Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule.	52
5.	Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule.	63

LIST OF ILLUSTRATIONS

Figure	Page
1. Hypothetical data which illustrate behavioral contrast.	2
2. The rate of responding, in responses per minute, in each component of the multiple schedules for subject W3.	18
3. Continuation of Figure 2.	19
4. The rate of responding, in responses per minute, in each component of the multiple schedules for subject W4.	20
5. Continuation of Figure 4.	21
6. The rate of responding, in responses per minute, in each component of the multiple schedules for subject W7.	22
7. The rate of responding, in responses per minute, in each component of the multiple schedules for subject W8.	23
8. The rate of responding, in responses per minute, in each component of multiple VI 1 min VI 1 min (first panel) and multiple VI 1 min VT 1 min (second panel). Data are for pigeon P3.	24
9. The relative rate of responding in the light stimulus for W12 and W13.	36
10. The relative amount of time spent in the light stimulus by subjects W12 and W13.	38
11. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subjects 39, 40, 102, and 103.	45
12. The total number of reinforcements obtained in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subjects 39, 40, 102, and 103.	48

Figure	Page
13. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject P99.	54
14. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W6.	55
15. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W11.	56
16. The rate of responding, in responses per minute, in both components of the multiple VI 1 min VI 1 min schedule. Data are for subject P3.	57
17. The total number of reinforcements obtained in each component of the multiple RI 25 sec RI 25 sec (subjects P99, W6, and W11) and multiple VI 1 min VI 1 min (subject P3) schedules.	61
18. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject P99.	64
19. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W6.	65
20. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W11.	66
21. The total number of reinforcements obtained in each component of the multiple RI 25 sec RI 25 sec schedule. Data are for subjects P99, W6, and W11.	69

ABSTRACT

On Some Determinants of Behavioral Contrast

by

Donald M. Wilkie

The conditions responsible for the behavioral contrast which typically occurs during differential reinforcement in multiple schedules were investigated in two sets of experiments. Several rats and a pigeon served as subjects. The first set of experiments dealt with the question of whether a reduction in the rate of responding in one component of a multiple schedule, apart from any reduction in reinforcement frequency, would produce behavioral contrast in the other component. When response rate was reduced and reinforcement frequency held constant by delivering reinforcement in one component of a multiple schedule independently of responding, no behavioral contrast was observed in the other component. This finding demonstrated that a reduction in the rate of responding in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast. It was also found in the first set of experiments that a reduction in the reinforcement frequency in one component of a multiple schedule was a sufficient condition for the occurrence of behavioral contrast.

The second set of experiments dealt with the question of whether a reduction in either response rate or reinforcement frequency in one component of a multiple schedule is a necessary condition for the

occurrence of behavioral contrast. When reinforcement in one component of a multiple schedule was briefly delayed, behavioral contrast was observed in the other component of the multiple schedule. The behavioral contrast occurred despite the fact that there was no general decrease in response rate in the delay component. This finding suggests that a reduction in response rate in one component of a multiple schedule is not a necessary condition for the occurrence of behavioral contrast. Some evidence suggesting that a decrease in reinforcement frequency in one component of a multiple schedule may not be necessary for the occurrence of behavioral contrast was also found.

The results of these experiments suggest that the change to a less preferred condition in one component of a multiple schedule is sufficient and necessary to produce behavioral contrast in the other component. Behavioral contrast was observed in the present experiments only when the conditions in one component of a multiple schedule were, less preferred, as measured in a choice situation, to the conditions prevailing in the other component.

CHAPTER I INTRODUCTION1. Behavioral contrast.

The establishment of stimulus control ¹ over an operant behavior through differential reinforcement is sometimes accompanied by an increased rate of responding during the stimulus correlated with reinforcement. This increased rate of responding is called "behavioral contrast" ² (Reynolds, 1961a). As an example of this effect, suppose that a pigeon was reinforced occasionally in the presence of two stimuli (S1 and S2) which were presented successively. If reinforcement was subsequently made no longer available during one of the stimuli (S2), the following would typically occur. First, the rate of responding during S2 would decrease to a low level. If this occurred and the bird continued to respond during S1, it could be said that the bird's responding was under stimulus control. Alternatively, it could be said that a discrimination between S1 and S2 had been formed or that the bird was discriminating S1 from S2. Second, the rate of responding during S1 would increase above the level prevailing when both S1 and

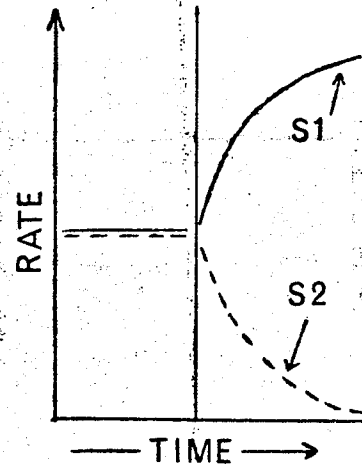
¹ Stimulus control (Terrace, 1966) refers to the relationship between antecedent stimuli and the probability of a conditioned response. Control by a stimulus is measured by the extent to which the probability of responding covaries with changes in the value of the stimulus on some continuum - the greater the correlation, the greater the degree of stimulus control.

The concept of stimulus control is similar to the traditional concepts of discrimination and generalization. However, the traditional terms have connotations not implied by the term stimulus control (Terrace, 1966; Gilbert, 1969). While both stimulus control and discrimination-generalization will be used interchangeably in the present paper, only the meaning of the former is intended.

² Effects similar to behavioral contrast have also been noted in respondent conditioning (Pavlov, 1927), runway experiments (eg. Amsel and Rousell, 1952), sensory systems (e.g. Ratliff et al, 1963), and in punishment studies (e.g. Azrin and Holz, 1966).

S2 were associated with reinforcement. This increased rate of responding during S1 is called behavioral contrast. Figure 1 illustrates the behavioral contrast effect.

Figure 1. Hypothetical data which illustrate behavioral contrast. Responding is originally reinforced in both S1 and S2. When reinforcement is no longer available during S2, the rate of responding during S2 decreases. The increased rate of responding during S1 is behavioral contrast.



Behavioral contrast is not a permanent change in the organism's behavior. Behavioral contrast disappears after extended exposure to differential reinforcement (Terrace, 1966). In the example given above, the rate of responding during S1 would eventually decrease to approximately its original level.

The occurrence of behavioral contrast typically coincides with several other effects. First, the rate of responding during the stimulus associated with reinforcement is highest immediately following presentation of the stimulus correlated with non-reinforcement. This effect has been called "transient contrast" (Nevin and Shettleworth, 1966). Second, the peak or mode of the post-discrimination generalization gradient is shifted in a direction away from the stimulus associated with non-reinforcement. This effect has been called the "peak shift" (Hanson, 1959). Third, if the stimuli correlated with rein-

forcement and non-reinforcement are from orthogonal stimulus continuums it can be shown that a gradient of non-responding, called a gradient of inhibition, exists around the stimulus associated with non-reinforcement (e.g. Jenkins, 1965; Honig et al, 1963).

2. The determinants of behavioral contrast.

Apart from their bearing on classical discrimination-generalization theory (Spence, 1936; Hull, 1952), behavioral contrast and the other effects associated with the establishment of stimulus control over operant behavior have been studied as empirical phenomena in and of themselves. Much of the recent research on these topics has been concerned with delineating the conditions under which they occur.

There has been a considerable amount of research directed at determining the conditions responsible for the occurrence of behavioral contrast. One important finding has been that the establishment of stimulus control per se does not produce behavioral contrast. If an "errorless discrimination" (Terrace, 1963) is established, behavioral contrast is not observed. Since few, if any, responses during the stimulus correlated with non-reinforcement occur during an "errorless discrimination," one necessary prerequisite for the occurrence of behavioral contrast appears to be responding during the stimulus associated with non-reinforcement.

Given that non-reinforced responding does occur during the establishment of stimulus control, what other conditions are necessary before behavioral contrast will occur? There have been several

suggestions as to what constitutes other necessary prerequisites for the occurrence of behavioral contrast. It has been suggested that behavioral contrast results from either (1) a reduced frequency of reinforcement (Reynolds, 1961a) or, (2) a reduced rate of responding (Terrace, 1966) during one of two successively presented stimuli. Since rate of responding and frequency of reinforcement tend to covary, these two processes are confounded in a simple differential reinforcement situation in which responding is reinforced in the presence of one stimulus and non-reinforced in the presence of another. Because of this, special techniques have had to be used to differentiate between the role of reductions in reinforcement frequency and response rate in the occurrence of behavioral contrast. Several experiments have been performed which do differentiate between a reduced rate of responding and a reduced frequency of reinforcement. These experiments have not, as yet, allowed a clear choice between these two accounts of behavioral contrast.

Evidence for the frequency of reinforcement hypothesis.

There are several experiments which support the frequency of reinforcement hypothesis of behavioral contrast. The first of these was performed by Reynolds (1961a). In this experiment pigeons were first reinforced for key pecking on a multiple³ variable-interval

³ A multiple schedule is one in which different stimuli are correlated with different schedules of reinforcement. For example, if variable-interval reinforcement was available during the presence of a tone and no reinforcement during the absence of the tone, the schedule would be called a multiple variable-interval -- extinction schedule. By convention, the term multiple schedule is also used to refer to a schedule in which different stimuli are correlated with identical schedules of reinforcement. Thus if the same variable-interval one minute schedule was programmed in both tone and no tone components, the schedule would be referred to as multiple variable-interval one minute - variable-interval one minute.

three minute variable-interval three minute (multiple VI 3 min VI 3 min) schedule. The components of the schedule were correlated with red and green key lights. After a period of training on this schedule, reinforcement in the presence of the green stimulus was made contingent upon the non-occurrence of key pecking for a period of 50 seconds (differential reinforcement for other behavior or DRO). Pecking in the red stimulus continued to be reinforced on the original VI 3 min schedule. This multiple VI 3 min DRO 50 sec schedule had the effect of reducing the rate of responding during the green stimulus while at the same time maintaining a more-or-less equal frequency of reinforcement in the two components. Under these conditions, no increased rate of responding during the red stimulus (behavioral contrast) was observed. This experiment suggested that a reduction in the frequency of reinforcement rather than a reduction in response rate was a necessary condition for the occurrence of behavioral contrast.

An experiment performed by Catania (1961) also supports the hypothesis that a reduced frequency of reinforcement in one stimulus produces behavioral contrast. In this experiment pigeons could respond on either of two keys. Originally a VI 3 min schedule was programmed on each key. Next, a multiple VI 3 min Extinction schedule was programmed on one of the keys; the original VI 3 min schedule remained on the other key. The rate of responding on both VI 3 min schedules increased as a result of this change. When the multiple schedule was later changed to multiple VI 1.5 min Extinction so that the rate of reinforcement on both keys was again equal, the behavioral contrast on the VI 3 min key was eliminated. This occurred despite

the continued reduction in response rate during the Extinction component of the multiple schedule.

Bloomfield (1967), in another experiment that supports the frequency of reinforcement hypothesis, trained pigeons on a series of two-component multiple schedules in which one component was always a VI 1 min schedule and the other component either, for different birds, a fixed-ratio (FR) or differential reinforcement for low rate (DRL) schedule. By varying the value of the FR, in which rate of responding and frequency of reinforcement are directly related, and the value of the DRL, in which response rate and reinforcement frequency are inversely related, Bloomfield found that similar changes in the reinforcement frequency in the FR or DRL component produced similar changes in the rate of responding in the constant VI 1 min component. This finding suggested that behavioral contrast is a function of reinforcement frequency rather than response rate.

Yarczower et al's (1968) experiment also supports the frequency of reinforcement hypothesis. In this experiment pigeons were first trained on a tandem VI 30 sec DRL 4 sec schedule. On this schedule a response initiated a DRL interval once every 30 seconds on the average; the next response which followed a preceding response by a period of 4 seconds was reinforced. After training on this schedule was completed, a multiple (tandem VI 30 sec DRL 4 sec) (DRO 10 sec) schedule was introduced. On this schedule pecking in one component of the multiple schedule was reinforced on the original tandem VI 30 sec DRL 4 sec schedule. In the other component the non-occurrence of key pecking

for a period of 10 seconds was reinforced. Despite the fact that the DRO 10 second component controlled a low rate of responding, no behavioral contrast was observed.

Similar results were found by Nevin (1968). In his experiment pigeons were first trained on a multiple VI 3 min VI 3 min schedule. One component was later changed so that the non-occurrence of pecking was reinforced. The non-occurrence of a key peck for a period of 10 seconds was reinforced on a VI schedule, the value of which was varied in different parts of the experiment. The value of this VI schedule controlled the frequency of reinforcement in this component. Nevin reported that behavioral contrast was observed only when the frequency of reinforcement in the DRO component was less than that in the VI 3 min component of the multiple schedule. This finding suggested that a reduced frequency of reinforcement in one component of a multiple schedule is a necessary prerequisite for the occurrence of behavioral contrast.

Evidence for the rate of responding hypothesis.

Several experiments have provided evidence favoring a rate of responding interpretation of behavioral contrast. These experiments have shown that a reduced response rate in one component of a multiple schedule, apart from any decrease in reinforcement frequency in this component, can produce behavioral contrast. One of these experiments was performed by Brethower and Reynolds (1962). In this experiment pigeons were first trained on a multiple VI 3 min VI 3 min schedule in which the components were correlated with red and green key lights.

When each response during the green stimulus was subsequently punished with shock, the rate of responding in this stimulus decreased. At the same time, the rate of responding during the red stimulus increased over its previous level. Behavioral contrast occurred in the red stimulus despite the fact that, at least for some subjects, the rate of responding in the green stimulus was sufficient to ensure a more-or-less equal frequency of reinforcement in both stimuli. Similar findings have been reported by Terrace (1968) in a replication of this experiment.

Further support for the rate of responding interpretation comes from an experiment by Reynolds and Limpo (1968). They trained pigeons on a multiple DRL 35 sec DRL 35 sec schedule. Later, an interresponse time clock was correlated with the passage of time during the DRL interval in one component of the multiple schedule. The addition of the clock decreased the rate of responding and increased the frequency of reinforcement in this component. In spite of the increased frequency of reinforcement in the component containing the clock, behavioral contrast was still observed in the unaltered component.

Terrace's (1968) experiment also supports the rate of responding hypothesis. In one experiment in this study pigeons were trained on a VI 1 min schedule. The birds were later shifted to a multiple VI 1 min DRL schedule. The value of the DRL was changed on a day-to-day basis to ensure that the frequency of reinforcement in the two components of the multiple schedule were approximately equal. Under these conditions in which the rate of responding in one component of the multiple

schedule was reduced, three of six birds showed behavioral contrast. A similar experiment was performed by Weisman (1969). Weisman also found behavioral contrast in the VI component of a multiple VI DRL schedule in which the frequency of reinforcement in the two components was more-or-less equal.

Two other experiments (Brownstein and Hughes, 1970; Brownstein and Newsom, 1970) support the rate of responding hypothesis. In the Brownstein and Hughes experiment pigeons were first trained on a multiple VI 1 min VI 1 min schedule. Later, a signalling procedure was added to one component of the multiple schedule. This procedure, which consisted of illuminating the response key only when a reinforcement was available on the VI schedule, reduced the rate of responding but not the frequency of reinforcement in that component. Despite equal reinforcement frequency in the two components, behavioral contrast still occurred in the unchanged component. Similar findings with fixed-interval schedules were found by Brownstein and Newsom.

Bloomfield's hypothesis.

In addition to the rate of responding and frequency of reinforcement hypotheses previously considered, a third account of the conditions responsible for behavioral contrast has been developed. This account (Bloomfield, 1969) states that behavioral contrast results from a "worsening of conditions" during one of two successively presented stimuli. By "worsening of conditions" Bloomfield apparently means a change in conditions which results in the original condition

being preferred to the new condition. Preference can be determined in a choice situation: an organism is said to prefer one condition to another if it spends more time in its presence than in the presence of another condition when both conditions are available to the organism. The change from reinforcement to extinction in one component of a multiple schedule is a good example of "worsening of conditions" since organisms typically prefer reinforcement to non-reinforcement in a choice situation.

Bloomfield's hypothesis can account for several of the findings considered in the review of the evidence for the rate of responding and frequency of reinforcement hypotheses. Since deprived organisms will generally prefer a higher to a lower frequency of reinforcement, studies in which behavioral contrast appears to be related to the reduction in reinforcement frequency could be subsumed under Bloomfield's hypothesis. Similarly, several studies supporting the rate of responding interpretation also appear to support Bloomfield's account of behavioral contrast. For example, Terrace's (1968) and Weisman's (1969) findings for multiple VI DRL could be accounted for by Bloomfield's hypothesis since it is known (Fantino, 1968) that pigeons prefer schedules in which there is no required rate of responding such as the low rate required under DRL schedules. Also, Brethower and Reynolds' (1962) and Terrace's (1968) finding that punishment superimposed on the VI schedule in one component of a multiple VI VI schedule resulted in behavioral contrast in the non-punishment component could be accounted for by Bloomfield's hypothesis since it has been shown (e.g. Azrin and Holz, 1966) that organisms prefer non-punishment to

punishment in a choice situation.

3. Purpose of the present research: an investigation of the conditions responsible for behavioral contrast.

The research reported here attempted to provide additional information on the conditions that are responsible for the behavioral contrast observed in multiple schedules of reinforcement. Two sets of experiments are reported. The first set of experiments, reported in Chapter II, deals with the question of the role of a reduced rate of responding in the occurrence of behavioral contrast. The second set of experiments, reported in Chapter III, deals with the question of whether a reduction in either response rate or reinforcement frequency in one component of a multiple schedule is a necessary condition for the occurrence of behavioral contrast.

CHAPTER II SOME EXPERIMENTS WITH VARIABLE-TIME SCHEDULES1. Experiment I. Variable-time reinforcement in a multiple schedule.⁴

This experiment attempted to determine if a reduced rate of responding during one of two successively presented stimuli is a sufficient condition for the occurrence of behavioral contrast. As previously noted in Chapter I, special techniques have had to be used in attempts to determine if behavioral contrast is due to a reduced frequency of reinforcement or a reduced rate of responding in one component of a multiple schedule. These techniques have included the use of DRL and DRO schedules, punishment, clocks, and signalled reinforcement availability to reduce the rate of responding in one component of a multiple schedule while at the same time leaving the frequency of reinforcement in this component essentially unchanged. The present experiment made use of another technique which reduces response rate without changing the frequency of reinforcement. This technique consisted of delivering reinforcements in one component of a multiple schedule independently of the subjects' behavior. It is known that response-independent delivery of reinforcement reduces response rate (e.g. Zeiler, 1968; Rescorla and Skucy, 1969).

Method

Subjects. Four male albino rats, obtained from the Holtzman Co., served.

⁴ An experiment very similar to part of the present experiment has recently been performed by Weisman (1970). He trained pigeons first on a multiple VI 1 min VI 1 min schedule. The birds were later shifted to multiple VI 1 min VT 1 min in which reinforcements in one component were delivered independently of the birds' pecking on a variable-time schedule with an average inter-reinforcement interval of one minute. He found no behavioral contrast in the constant VI 1 min component despite the fact that the VT schedule reduced the rate of responding.

Subjects W3 and W4 were experimentally naive. Subjects W7 and W8 had previously served in an experiment involving fixed-ratio schedules. Subjects W3 and W4 were 180 days of age at the start of the experiment. The other two subjects were 190 days old. Prior to the start of the present experiment, all four subjects were reduced to 80 % of their normal free-feeding body weights by food deprivation. The subjects' 80 % weights were adjusted, on the basis of normal growth curves from Ezinga and Becker (in press), to control for normal growth during the course of the experiment. The subjects were maintained at 80 % normal body weight by food pellets obtained during experimental sessions and by supplements of Purina rat food given after experimental sessions. The subjects had free access to water in their home cages. The home cage water contained oxytetracycline hydrochloride (Terramycin) on approximately two-thirds of the experimental days.

An adult female homing pigeon, obtained locally, also served. The pigeon was reduced to 80 % of its normal free-feeding body weight by food deprivation. A grain mixture obtained during experimental sessions maintained the bird at 80 % normal body weight. Water and grit were always available in the home cage.

Apparatus. The experimental space used for the rats was a standard operant conditioning chamber for rodents (Lehigh Valley Electronics Model 1568 test cage and Model 1642 cubicle). The inner dimensions of the test space were 23 cm long, 20 cm wide, and 18 cm deep. On one wall of the test cage was mounted a lever and a 7 watt light source. The lever was mounted 4 cm above the grid floor of the test space. The light

source was mounted 4 cm directly above the lever. Operation of the lever required a force of approximately 6.5 grams (0.064N). Reinforcement consisted of 45 mg Noyes food pellets. The pellets were delivered by means of a standard pellet dispenser into a receptacle mounted 6cm to one side of the lever. A fan provided ventilation and a partial masking noise in the experimental space.

The experimental space used for the pigeon was a BRS-Foringer Model PH-004 pigeon chamber. The inner dimensions of the test space were 49 cm long, 34 cm high, and 35 cm deep. One wall of the test chamber contained three response keys, 3.2 cm in diameter, mounted 24 cm above the floor of the chamber. Only the center key was used in the present experiment. Operation of this key required a force of about 20 grams (0.196 N). Stimuli were projected on a screen mounted directly behind the response key by an Industrial Electronics Engineers' One-Plane Readout Cell. During the reinforcement period, stimuli on the response key were extinguished. Reinforcement consisted of 4 seconds access to a grain mixture presented by a standard grain feeder mounted directly below the center response key, 6 cm above the floor. A small light source illuminated the grain in the feeder tray during the reinforcement period. A fan provided ventilation and a partial masking noise in the experimental space.

Experimental contingencies and events in both test chambers were programmed with standard relay-type equipment. Data were recorded on digital impulse counters and cumulative recorders.

Procedure. Following a short period of preliminary training in which

lever pressing was conditioned, subjects W3 and W4 were placed on a two-component multiple schedule. Subjects W7 and W8, after a few sessions on a VI 30 sec schedule, were placed on the same multiple schedule. The components of the multiple schedule were correlated with light (C1) and darkness (C2) in the experimental space. Both components lasted for a period of 5 minutes. The components alternated with each other throughout the session. Originally, both C1 and C2 were associated with a VI 30 sec schedule of reinforcement. Later, the schedule in C2 was either: (1) a non-contingent schedule in which reinforcements were delivered, independently of lever pressing, after variable time (VT) periods averaging 30 seconds (VT 30 sec), (2) an extinction schedule in which no reinforcements were delivered, or (3) the original, response-contingent, VI 30 sec schedule. In addition, subjects W7 and W8 received two sessions in which a differential reinforcement for other behavior (DRO) schedule and the VT 30 sec schedule were combined in C2. This schedule is described in more detail in the Results section.

Sessions consisted of 5 presentations of each component. Sessions always began with the C1 component. The subjects received 7 daily sessions each week. Sessions occurred at about the same time each day.

The procedure for subjects W3, W4, W7, and W8 is outlined in Table 1.

The pigeon was placed on a multiple VI 1 min VI 1 min after a short period of preliminary training in which key pecking was conditioned. The components of the multiple schedule were correlated with a white line on a black background (C1) and a yellow-green light (C2)

projected on the rear of the response key. The components were 5 minutes in duration and were presented in strict alternation. After 16 sessions on multiple VI 1 min VI 1 min, the bird was placed on a multiple VI 1 min VT 1 min schedule for 11 sessions. On this schedule key pecking during C1 was reinforced as before on a VI 1 min schedule; in the C2 component reinforcements were presented independently of key pecking once every 1 minute on the average.

Table 1

Schedules, in order of presentation	Summary of Procedure	
	Number of sessions on schedule	
	W3 and W4	W7 and W8
A. multiple VI 30 VI 30	18	14
B. multiple VI 30 VT 30	15	21*
C. multiple VI 30 Extinction	13	9
D. multiple VI 30 VT 30	7	6
E. multiple VI 30 VI 30	16	8
F. multiple VI 30 VT 30	18	14
G. multiple VI 30 Extinction	7	-
H. multiple VI 30 VT 30	5	-
I. multiple VI 30 VI 30	3	-
J. multiple VI 30 VT 30	14 (18 for W4)	-

* The 15th and 16th sessions on this schedule had a DRO 10 second schedule superimposed on the VT 30 sec schedule. See text for details.

All sessions for the pigeon began in either C1 or C2, which was varied across days, and were one hour in duration. Sessions occurred at about the same time each day. Seven sessions were given each week.

Additional aspects of the procedure are discussed in more detail in the Results section.

Results

Figures 2 to 8 show the rate of responding in each component

of the multiple schedules for subjects W3 (Figures 2 and 3), W4 (Figures 4 and 5), W7 (Figure 6), and W8 (Figure 7) and the pigeon, P3 (Figure 8). The lettered panels of Figures 2 to 7 correspond to the multiple schedules outlined in Table 1. Thus the "A" panels refer to the sessions on multiple VI 30 sec VI 30 sec, the "B" panels to multiple VI 30 sec VT 30 sec and so forth. The first panel of Figure 8 is the sessions on multiple VI 1 min VI 1 min; the second panel is the sessions on multiple VI 1 min VT 1 min.

After obtaining a baseline on multiple VI VI, the subjects were shifted to multiple VI VT. This schedule change was of primary interest in the experiment. It was hoped that this change from VI to VT in C2 of the multiple schedule would allow an assessment of the role of a reduced response rate in one component of a multiple schedule in the occurrence of behavioral contrast. If a reduced rate of responding in one component of a multiple schedule is a sufficient condition to produce behavioral contrast, one would expect that the rate of responding in C1 would increase after the introduction of the multiple VI VT schedule.

As can be seen in Figures 2, 4, and 8, the shift from VI to VT in C2 of the multiple schedule reduced the rate of responding in this component for subjects W3, W4, and P3. It is less clear that the shift from VI to VT in C2 reduced the rate of responding in C2 for subjects W7 or W8 (Figures 6 and 7). This is particularly true for subject W8 who responded at a lower rate during C2 in the original baseline condition. Since these two subjects were not showing clear differential responding under the multiple VI VT schedule, a differential reinforce-

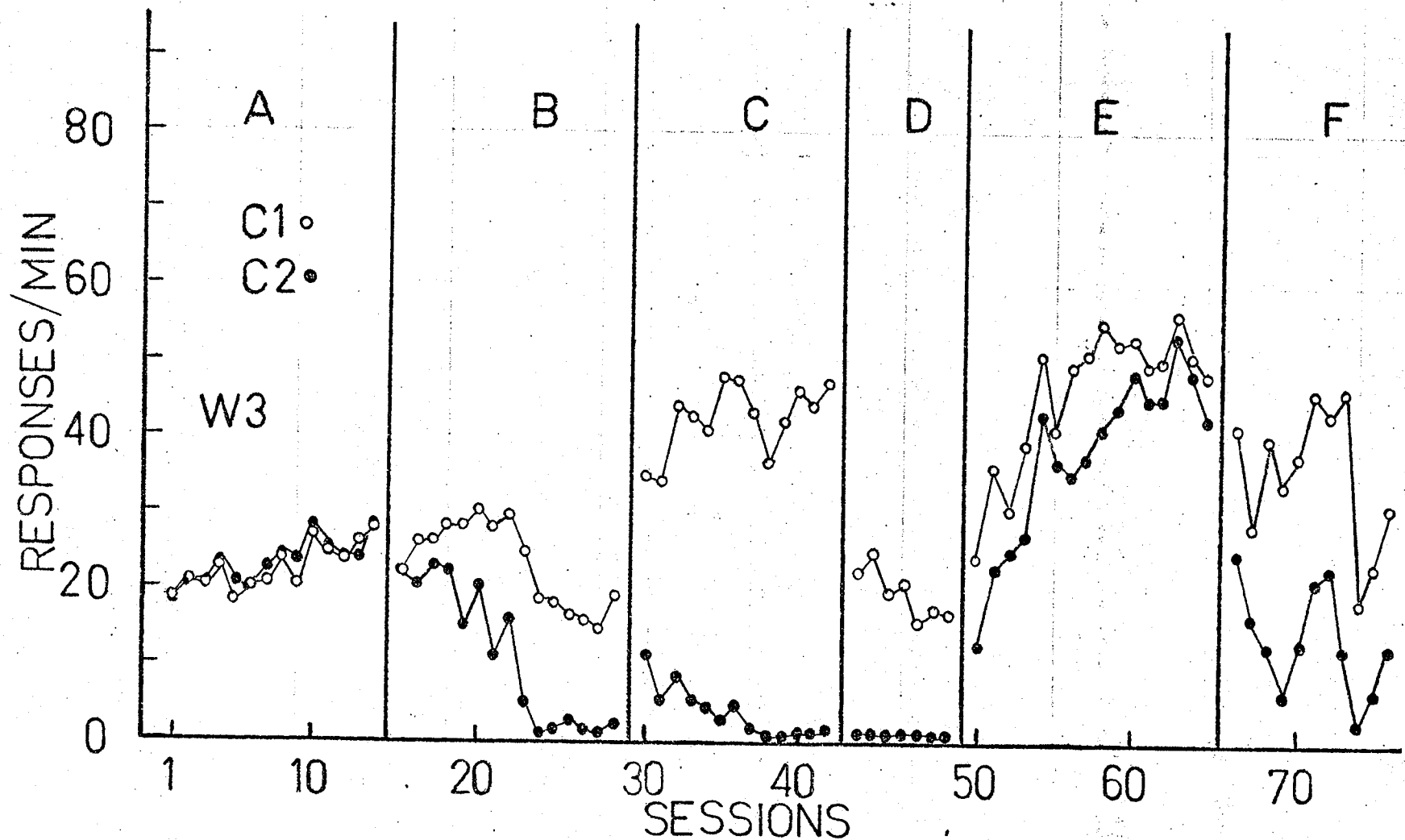


Figure 2. The rate of responding, in responses per minute, in each component of the multiple schedules for subject W3. The letters correspond to the multiple schedules outlined in Table 1. The C1 component was always VI 30 sec. The C2 component was VI 30 sec (A), VT 30 sec (B), Extinction (C), VT 30 sec (D), VI 30 sec (E), or VT 30 sec (F).

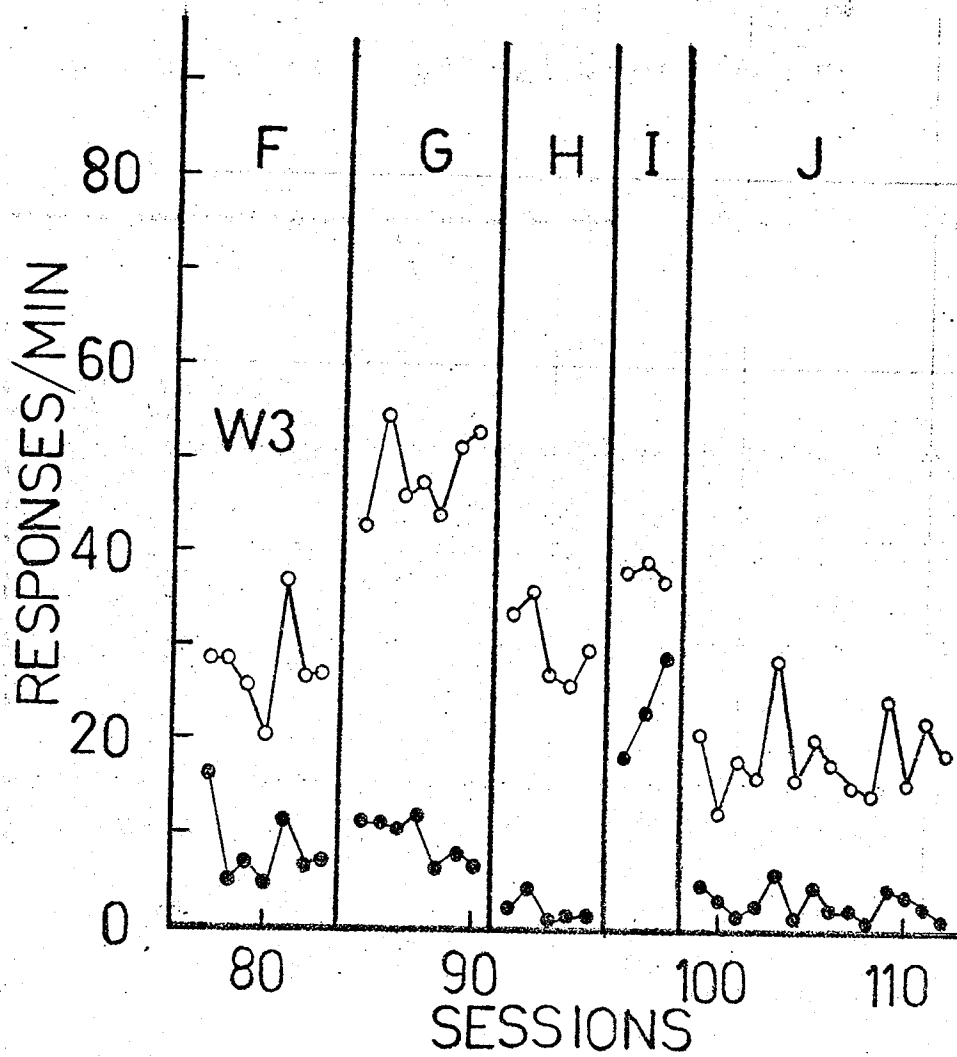


Figure 3. Continuation of Figure 2. The C2 schedules shown are VT 30 sec (F), Extinction (G), VT 30 sec (H), VI 30 sec (I), and VT 30 sec (J).

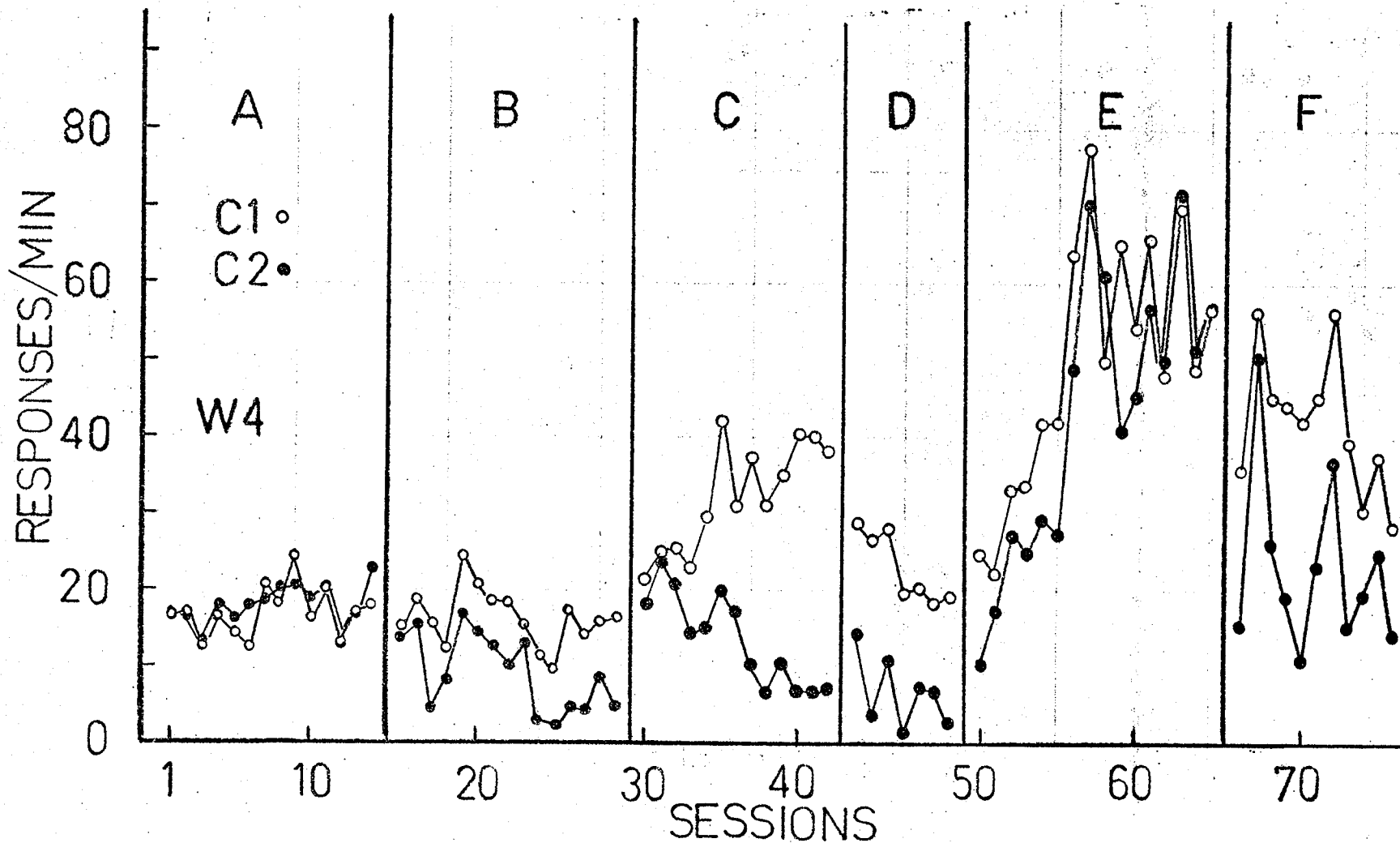


Figure 4. The rate of responding, in responses per minute, in both components of the multiple schedules for subject W4. The letters correspond to the multiple schedules outlined in Table 1. The C2 component was always VI 30 sec. The C1 component was VI 30 sec (A), VT 30 sec (B), Extinction (C), VT 30 sec (D), VI 30 sec (E), or VT 30 sec (F).

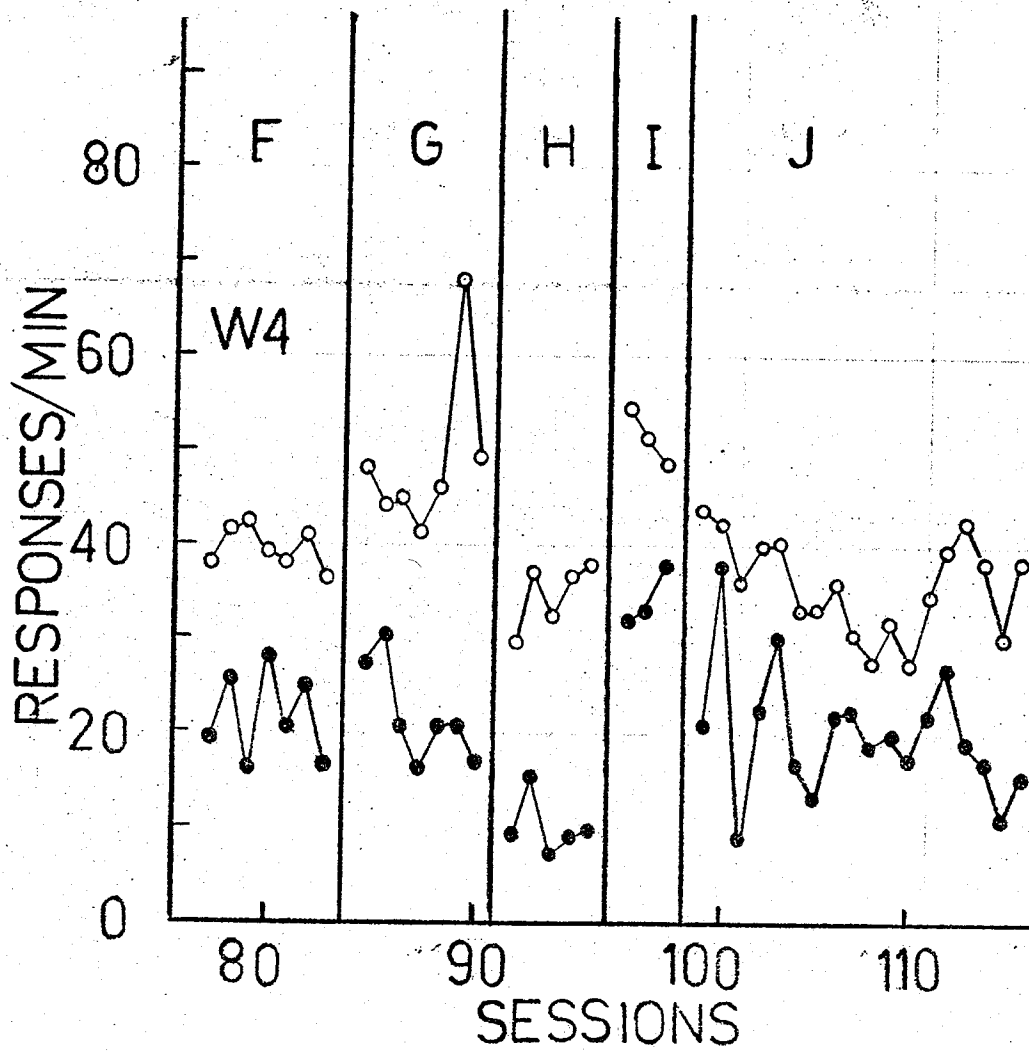


Figure 5. Continuation of Figure 4. The C2 schedules shown are VT 30 sec (F), Extinction (G), VT 30 sec (H), VI 30 sec (I), and VT 30 sec (J).

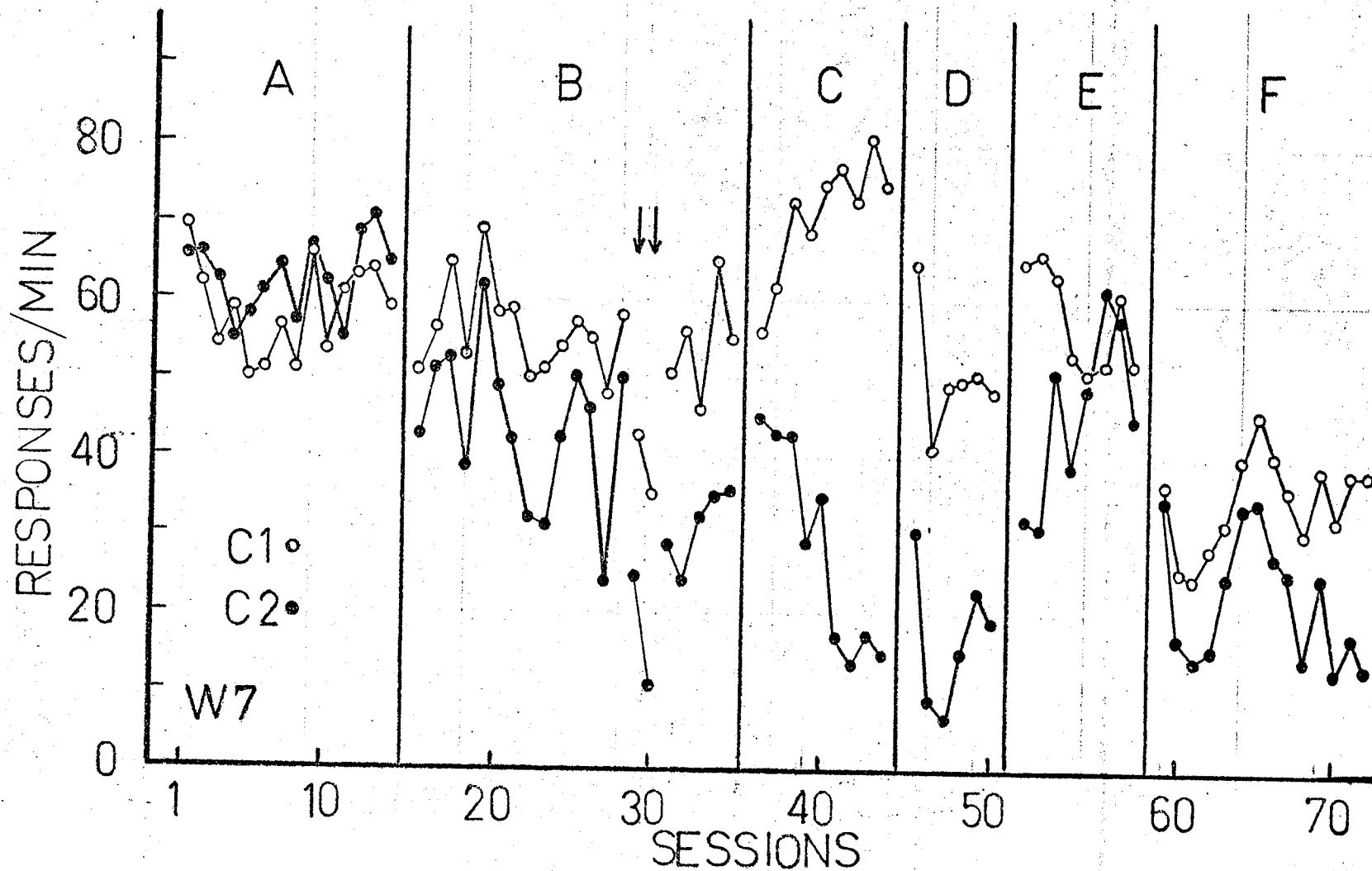


Figure 6. The rate of responding, in responses per minute, in both components of the multiple schedules for W7. The schedule in C1 was always VI 30 sec. The schedule in C2 was either VI 30 sec (A), VT 30 sec (B), Extinction (C), VT 30 sec (D), VI 30 sec (E), or VT 30 sec (F). The sessions in panel B indicated by the arrows had a DRO 10 sec schedule superimposed on the VT 30 sec component.

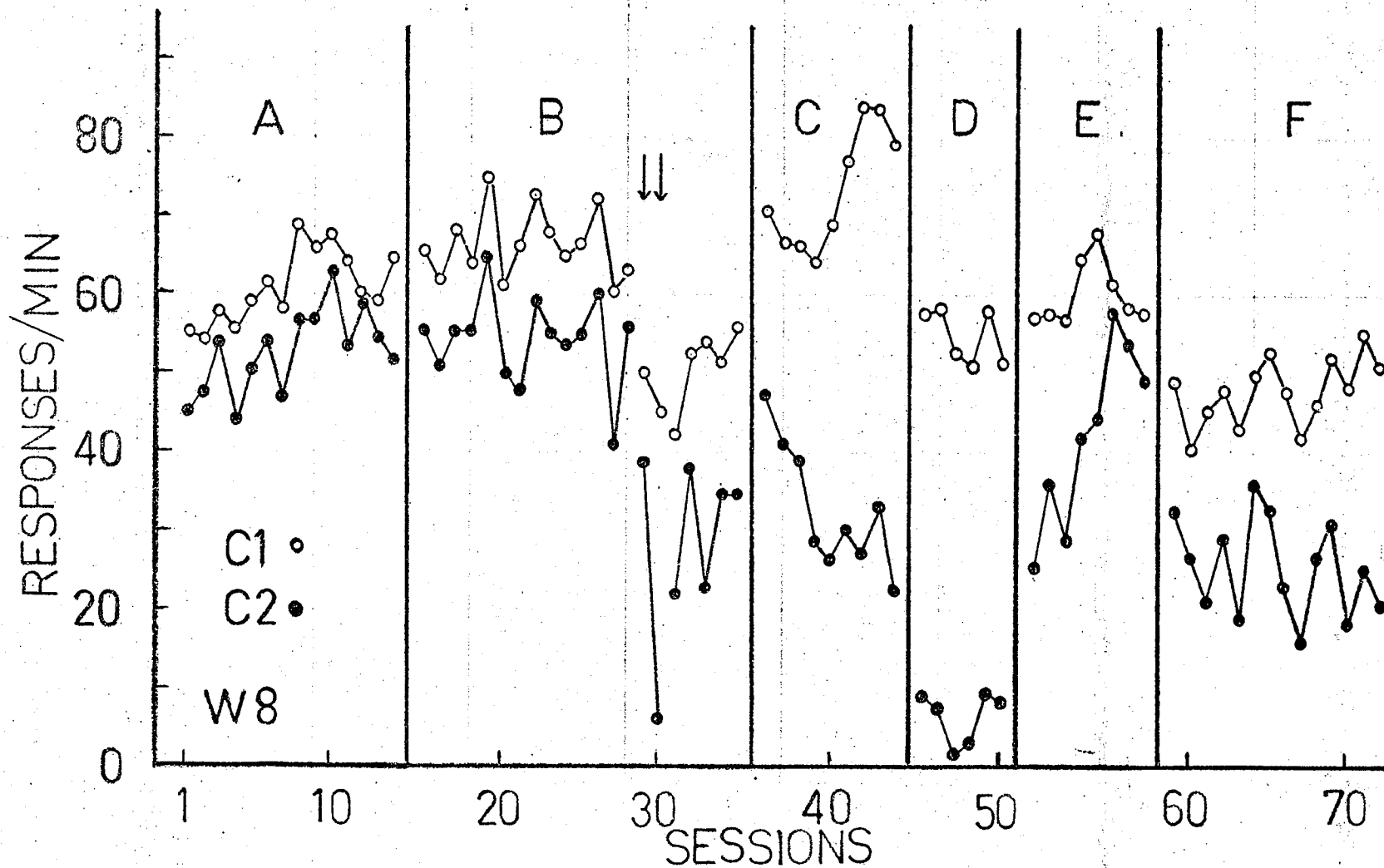


Figure 7. The rate of responding, in responses per minute, in both components of the multiple schedules for subject W8. The schedule in C1 was always VI 30 sec. The schedule in C2 was VI 30 sec (A), VT 30 sec (B), Extinction (C), VT 30 sec (D), VI 30 sec (E), or VT 30 sec (F). The sessions indicated by the arrows in panel B had a DRO 10 sec superimposed on the VT 30 sec component.

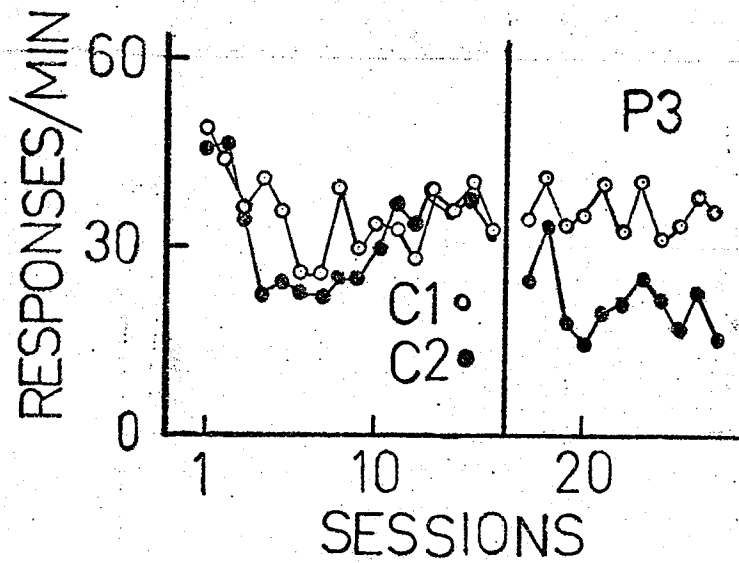


Figure 8. The rate of responding, in responses per minute, in each component of multiple VI 1 min VI 1 min (first panel) and multiple VI 1 min VT 1 min (second panel). Data are for pigeon P3.

ment for other behavior schedule (DRO) was superimposed on the VT 30 sec component for the two sessions indicated by the arrows in Figures 6 and 7. Under this schedule of reinforcement, reinforcement was delivered irrespective of lever pressing on the VT schedule. However, in addition, any period of 10 seconds in which no responses occurred also produced a reinforcement. This schedule combination had the desired effect of reducing the response rate in the C2 component. When the DRO contingency was removed after two sessions, the C2 response rate remained at a level lower than that prevailing before the introduction of this contingency. The addition of the DRO contingency to the VT component appeared to allow the subjects to be exposed to the VT schedule. These two subjects, who had a history of fixed-ratio schedules, had a considerably higher response rate in both components of the multiple schedule than the other subjects. This relatively high response rate probably prevented the subjects from being exposed to the VT schedule. It should be noted that the addition of the DRO contingency to the C2 component also reduced the rate of responding in the C1 component for both subjects. The reduction appeared to be permanent for subject W8.

During the period when C2 response rate was reduced by the VT schedule, no evidence of an increased rate of responding in C1 (ie. behavioral contrast) was observed. To the contrary, at least two subjects (W3 and W8) showed a small decrease in C1 response rate under the multiple VI 30 sec VT 30 sec schedule. It is less clear whether the C1 response rate was reduced for the other two rats. This was particularly true for subject W4.

The results of the shift from multiple VI VI to multiple VI VT suggest that a reduced response rate in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast. The shift from multiple VI 30 sec VT 30 sec to multiple VI 30 sec Extinction did, however, produce behavioral contrast for all four subjects (C panels of Figures 2, 4, 6, and 7). Behavioral contrast in the C1 component emerged in spite of the fact that the Extinction component controlled about the same rate of responding as did the VT component under multiple VI VT. Only in the case of one subject, W7, did the Extinction schedule control a lower rate of responding than the previous VT schedule. Thus, while both the VT and Extinction schedules controlled approximately the same rate of responding, only the Extinction schedule, in which no reinforcements were delivered, produced behavioral contrast in the constant VI 30 sec component. This finding tends to support the frequency of reinforcement hypothesis of behavioral contrast. Further evidence for this comes from the fact that the behavioral contrast occurring under the multiple VI 30 sec Extinction schedule was eliminated when the subjects were returned to the multiple VI 30 sec VT 30 sec schedule (D panels of Figures 2, 4, 6, and 7).

When the subjects were returned to the baseline multiple VI 30 sec VI 30 sec schedule an unexpected effect was observed. One might have expected that the rate of responding in the component changed from VT 30 sec to VI 30 sec would gradually increase to about the level prevailing in C1. Instead, the rate of responding in both C1 and C2 increased (E panels of Figures 2, 4, 6, and 7). The rate

increase for subjects W3 and W4 was particularly large. The effect for the other two subjects was considerably smaller but nevertheless evident. When the subjects were next switched to multiple VI 30 sec VT 30 sec, the rate of responding in both C1 and C2 decreased with the rate in the VT component decreasing more than the rate in the VI component (F panels of Figures 2, 4, 6, and 7). This result was somewhat similar to the rate changes observed, especially for subject W3, when the schedule was first switched from multiple VI 30 sec VI 30 sec to multiple VI 30 sec VT 30 sec (B panels).

Subjects W3 and W4 were next exposed to multiple VI 30 sec Extinction, multiple VI 30 sec VT 30 sec, multiple VI 30 sec VI 30 sec, and multiple VI 30 sec VT 30 sec (panels G, H, I, and J of Figures 2 and 4). This series of schedules replicated the major findings observed earlier in the experiment. The shift from multiple VI 30 sec VT 30 sec to multiple VI 30 sec Extinction produced behavioral contrast in the constant VI 30 sec component. The shift from multiple VI 30 sec Extinction to multiple VI 30 sec VT 30 sec eliminated the contrast. The change from multiple VI 30 sec VT 30 sec to multiple VI 30 sec VI 30 sec produced a rate increase in both components. The rate of responding in both components decreased with the rate in the C2 component decreasing more than the C1 rate when the subjects were shifted from multiple VI 30 sec VI 30 sec to multiple VI 30 sec VT 30 sec.

It should be noted that, with the exception of the multiple VI 30 sec Extinction schedule, the frequency of reinforcement in the two components of the multiple schedule used in the present experiment were essentially the same.

Discussion

The results of this experiment suggest that a reduction in the rate of responding in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast. While a reduced rate of responding in one component of a multiple schedule may be a necessary condition for the occurrence of behavioral contrast, a reduced rate of responding by itself does not appear to account for the occurrence of behavioral contrast. It could be argued, however, that contrast depends in some way on the amount of response suppression obtained in one component of a multiple schedule. That is, the failure to find behavioral contrast on the multiple VI VT schedules may have been due to the rather small amount of response suppression typically produced by the VT schedule. While this argument may appear plausible, it does not appear to be supported by the findings of other experiments (e.g. Weisman, 1969) where contrast was reported with only relatively small reductions in response rate in one component of a multiple schedule. Also, this argument is not supported by the finding in the present experiment that the C1 response rate increased after C2 was changed from VT to Extinction despite the fact that both VT and Extinction schedules controlled about the same rate of responding.

The results of this experiment seem to implicate a change in reinforcement frequency rather than a change in response rate in the occurrence of behavioral contrast. Behavioral contrast was observed only when the subjects were shifted from multiple VI 30 sec VT 30 sec to multiple VI 30 sec Extinction. The contrast observed on the

multiple VI 30 sec Extinction schedule occurred in spite of the fact that the VT and Extinction schedules controlled a more-or-less equal rate of responding. Further evidence for the frequency of reinforcement interpretation comes from the fact that the contrast observed on multiple VI 30 sec Extinction was eliminated after the switch to multiple VI 30 sec VT 30 sec. Contrast was eliminated when reinforcement was again available in C2 of the multiple schedule. Another finding supporting the reinforcement frequency interpretation was the reduction in the VI 30 sec response rate observed when the DRO schedule was superimposed on the VT component. This schedule combination greatly increased the frequency of reinforcement in the VT component.

One finding in the present experiment is rather puzzling. This is the increased rate of responding observed in both components of the multiple schedule when the subjects were shifted from multiple VI 30 sec VT 30 sec to multiple VI 30 sec VI 30 sec. The fact that the rate of responding increased in both components is difficult to explain. However, it should be noted that somewhat similar findings have been observed in our laboratory when rats are shifted from multiple VI Extinction to multiple VI VI. A similar effect is reported in an experiment in Chapter III.

2. Experiment II. Variable-time reinforcement in a concurrent schedule.

The results of the preceding experiment suggested that a reduced response rate in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast. The

results appeared to support the rate of reinforcement interpretation of behavioral contrast. However, the results also appear, on an intuitive basis at least, to support Bloomfield's interpretation that behavioral contrast is due to a "worsening of conditions" in one component of a multiple schedule. The failure to find behavioral contrast on the multiple VI VT schedule is not inconsistent with Bloomfield's hypothesis since it is difficult to conceive of the change from a VI to a VT schedule as a "worsening of conditions". On the other hand, the change to multiple VI Extinction, where behavioral contrast was observed, could be thought of as a change for the worse since this change involved a reduction in reinforcement frequency in one component of a multiple schedule. While Bloomfield's hypothesis is concerned only with response rate increases resulting from a worsening of conditions, it is possible that response rate decreases in one component of a multiple schedule may be due to a "bettering of conditions" (ie. a shift to a more preferred condition) in the other component. Some evidence for this comes from the fact that the VI response rate was reduced when reinforcement frequency in the other component was increased under the combination of VT and DRO schedules.

The present experiment sought to provide some experimental verification of Bloomfield's hypothesis. More specifically, the present experiment sought to determine if a shift from VI to VT does involve a worsening of conditions. Since contrast was not observed on the multiple VI VT schedule, one would expect, on the basis of Bloomfield's hypothesis, that subjects would show no preference for the VI schedule in a situation where they could choose between a

VI and VT schedule that provided an equal frequency of reinforcement. Preference was ascertained in a concurrent VI VT schedule in which both a VI and a VT schedule were available to the subject.

Method

Subjects. Two adult male albino rats served. The subjects were obtained from the Holtzman Co. Both subjects were experimentally naive and were 152 days of age at the start of the experiment. The subjects were reduced to 80 % of their normal free feeding body weights by food deprivation. Allowance for normal growth, on the basis of data from Ezinga and Becker (in press), was made in calculating the subjects' 80 % body weights. The subjects were maintained at their 80 % weights by milk obtained during experimental sessions and by supplements of Purina rat food given after experimental sessions. The subjects had free access to water in their home cages. The home cage water contained oxytetracycline hydrochloride (Terramycin) on about two-thirds of the experimental days.

Apparatus. The experimental space consisted of a standard operant conditioning chamber (Lehigh Valley Electronics Model 1316 test cage and Model 1316C cubicle). The test space was 30 cm long, 19 cm high, and 20 cm deep. The chamber contained a dipper feeder for delivering reinforcement, a 7 watt houselight, and two identical response levers which required a force of about 24 grams (0.235 N) to operate. Reinforcement consisted of 0.01 ml of a mixture of sweetened condensed milk and water (50 % of each by volume).

Experimental contingencies and events were programmed with solid state digital logic. The concurrent schedules were programmed

with a BRS-Foringer FP-8 two-channel tape reader. Data were recorded on digital impulse counters.

Procedure. Before the experiment proper began, the two subjects were given a short period of preliminary training during which lever pressing was conditioned. Following this period of pretraining, the subjects were placed on a concurrent VI 60 sec VI 60 sec schedule. The concurrent schedule was programmed with a changeover-lever procedure (Findley, 1958) in which the two VI 60 sec schedules were correlated with different stimuli (light and darkness in the experimental space). Two levers were used. Responses on one lever, the changeover-lever, changed the stimulus condition from light to dark and vice versa. Responding on a second lever, the schedule lever, was reinforced on the schedule associated with the prevailing stimulus condition. Responding on the schedule lever was never reinforced immediately following a response on the changeover-lever. Instead, a response on the changeover-lever initiated a changeover delay period of 2 seconds during which time reinforcement was not available for responding on the schedule lever.

In order to ensure an equal rate of reinforcement in the two stimulus conditions, a procedure similar to one described by Stubbs and Pliskoff (1969) was used. A two-channel tape reader assigned the reinforcements. One channel assigned reinforcements in the light condition; one channel assigned reinforcements in the dark condition. Reinforcements in the light and dark conditions were assigned at irregular intervals averaging one reinforcement assignment per minute for each condition. Once a reinforcement was assigned in either stimulus condition

the tape drive was stopped until that reinforcement was obtained. This procedure ensured that the frequency of reinforcement in the two stimuli (light and darkness) was equal.

After 28 sessions on this concurrent VI 60 sec VI 60 sec schedule, the subjects were shifted to a concurrent VI 60 sec VT 60 sec schedule. This schedule was similar to the concurrent VI 60 sec VI 60 sec schedule in all respects except that reinforcement during the light stimulus were no longer contingent upon lever pressing. The 2 second delay between a response on the changeover-lever and the availability of reinforcement was maintained in both stimulus conditions.

One subject, W13, did not appear to be making contact with the VT 60 sec component of the concurrent VI 60 sec VT 60 sec schedule even after 10 sessions on the schedule. This appeared to be due to this subject's high rate of responding (about 70 responses per minute) in both the VI and VT components. To bring this subject into contact with the VT schedule, reinforcements in the light condition were delivered only after a short period (5-10 seconds) of non-responding for three sessions. During these three sessions the experimenter manually withheld programmed reinforcements during the light condition until a 5-10 second period of non-responding had elapsed. After these three sessions the subject was returned to the regular concurrent VI 60 sec VT 60 sec schedule.

The subjects were finally placed on the original concurrent VI 60 sec VI 60 sec schedule in which reinforcements in both the light and dark stimuli were contingent upon lever pressing.

Summary details of the procedure for both subjects are shown in

Table 2. Omitted from the table are the three sessions for subject W13 in which reinforcement in the light stimulus was contingent upon a short period of non-responding.

Table 2

Summary of Procedure: Concurrent Schedules				
Schedule in		Number of Sessions		
Dark	Light	W12	W13	
concurrent VI 60	VI 60	28	28	
concurrent VI 60	VT 60	13	17	
concurrent VI 60	VI 60	14	7	

Throughout the experiment, 45 minute sessions were given 7 days a week. Sessions occurred at approximately the same time each day. Sessions began in either the light or dark component which was varied across days.

Results

One measure of interest in this experiment was the relative rate of responding in the light stimulus, defined as -

$$\text{Relative response rate (Light)} = \frac{\text{response rate in light}}{\text{response rate in light} + \text{response rate in dark}}$$

This measure is of relevance in determining if the introduction of the concurrent VI 60 sec VT 60 sec schedule reduced the rate of responding in the VT 60 sec component. If the rate of responding in the two stimuli were equal this ratio would equal 0.50. If the response rate in the light was greater than the response rate in the dark, this ratio would be greater than 0.50. The ratio will be less than 0.50 if the response rate in light is less than the response rate in the dark.

After the introduction of the VT 60 sec schedule in the light

stimulus, one would expect that the relative response rate in the light to decrease below 0.50. One would also expect that this ratio would be about 0.50 under the concurrent VI 60 sec VI 60 sec schedule. Figure 9 shows, for the two subjects, the actual relative rate of responding in the light component for the three stages of the experiment: concurrent VI 60 sec VI 60 sec, concurrent VI 60 sec VT 60 sec, and concurrent VI 60 sec VI 60 sec. These three stages are represented by panels A, B, and C respectively in Figure 9. As can be seen from panel A, the relative rate of responding in the light was approximately 0.50 for both subjects. This indicates a more-or-less equal rate of responding in the light and dark stimuli when these stimuli were both associated with the VI 60 sec schedule. When the concurrent VI 60 sec VT 60 sec schedule was introduced (panel B), the relative rate of responding in the light decreased for subject W12 indicating a lower response rate on the VT 60 sec schedule. Subject W13 did not show this effect until he was reinforced for three sessions for not responding in the light stimulus. After these sessions, indicated by the arrow in Figure 9, this subject also showed a decreased relative response rate in light. When the subjects were returned to concurrent VI 60 sec VI 60 sec (panel C), the relative response rate in light increased to approximately 0.50. These data indicate that both stimuli controlled a more-or-less equal rate of responding on concurrent VI 60 sec VI 60 sec. On concurrent VI 60 sec VT 60 sec, the light stimulus controlled a lower rate of responding.

The measure of central interest in this experiment was the relative amount of time spent by the subjects in the presence of the

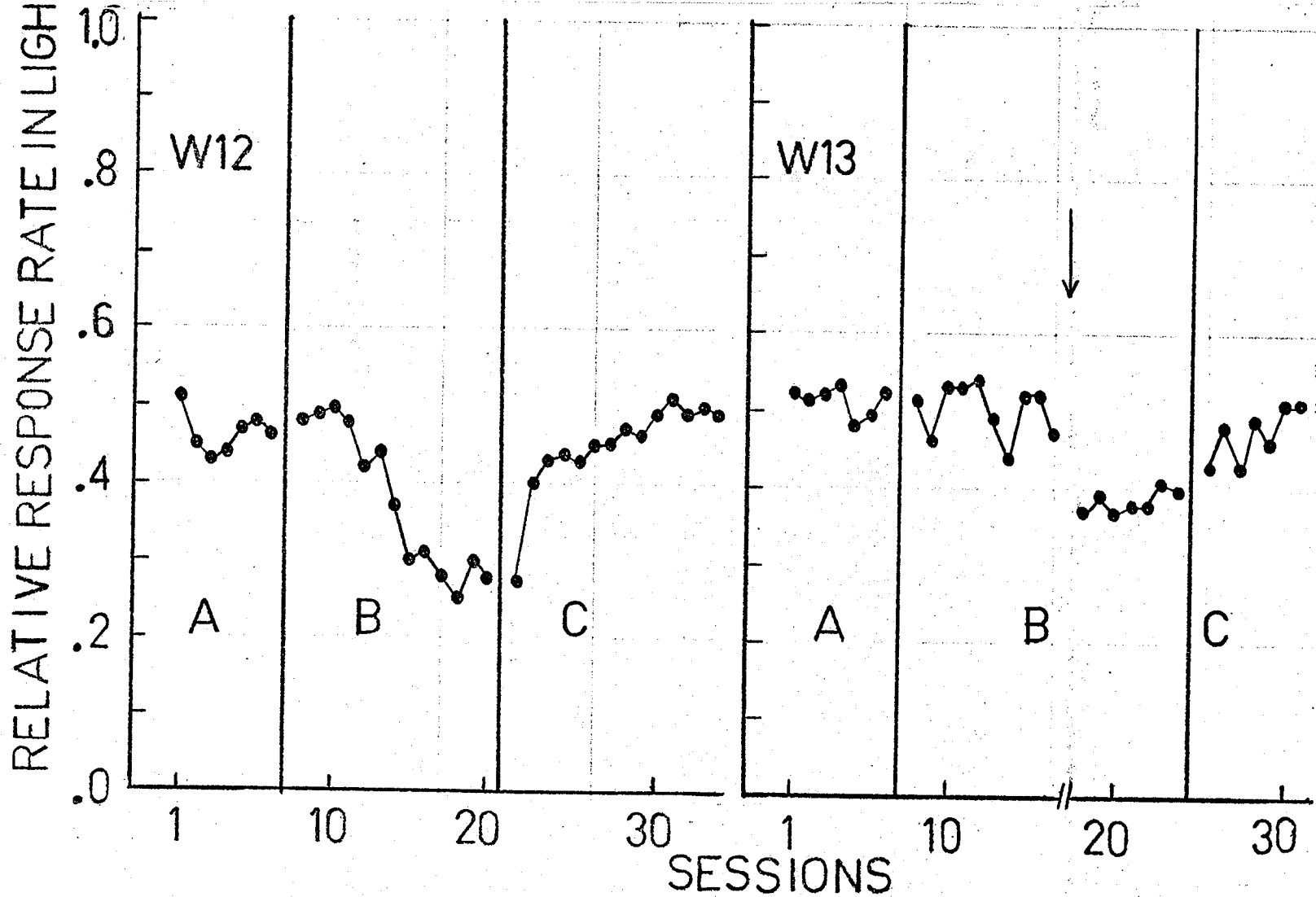


Figure 9. The relative rate of responding in the light stimulus for W12 and W13. Panel A shows the last 7 sessions on concurrent VI 60 sec VI 60 sec. Panel B shows the sessions on concurrent VI 60 sec VT 60 sec. The arrow shows where subject W13 was reinforced for not responding for three sessions. These three sessions are omitted from the figure. Panel C shows the final sessions on concurrent VI 60 sec VI 60 sec.

light stimulus, defined as -

$$\text{Relative time (Light)} = \frac{\text{time spent in light}}{\text{time spent in light} + \text{time spent in dark}}$$

This measure indicates the degree of preference for a stimulus condition in a concurrent schedule. If this ratio equals 0.50, no preference exists. If this ratio is greater than 0.50, the subject prefers the light stimulus. A ratio of less than 0.50 indicates a preference for the dark condition.

One would expect a relative time ratio of about 0.50 on the concurrent VI 60 sec VI 60 sec . One would expect, on the basis of Bloomfield's hypothesis, that the ratio would remain at 0.50 on the concurrent VI 60 sec VT 60 sec schedule even when the VT 60 sec schedule controls a lower rate of responding than the VI 60 sec schedule. Figure 10 shows the actual relative times obtained during the three stages of the experiment: concurrent VI 60 sec VI 60 sec (panel A), concurrent VI 60 sec VT 60 sec (panel B), and concurrent VI 60 sec VI 60 sec (panel C).

From panel A of Figure 10 it can be seen that the subjects spent about an equal amount of time in the light and dark stimuli while on the concurrent VI 60 sec VI 60 sec schedule. This is particularly true of subject W13. Subject W12 tended to spend more time in the light component but this preference for the light stimulus was fairly small. Panel B of Figure 10 shows the relative time spent in the light stimulus under concurrent VI 60 sec VT 60 sec. Neither of the subjects showed a preference for the VI 60 sec schedule over the VT 60 sec schedule. Subject W13 may have showed a slight preference for the VT 60 sec schedule but this effect was relatively small. In any event, the

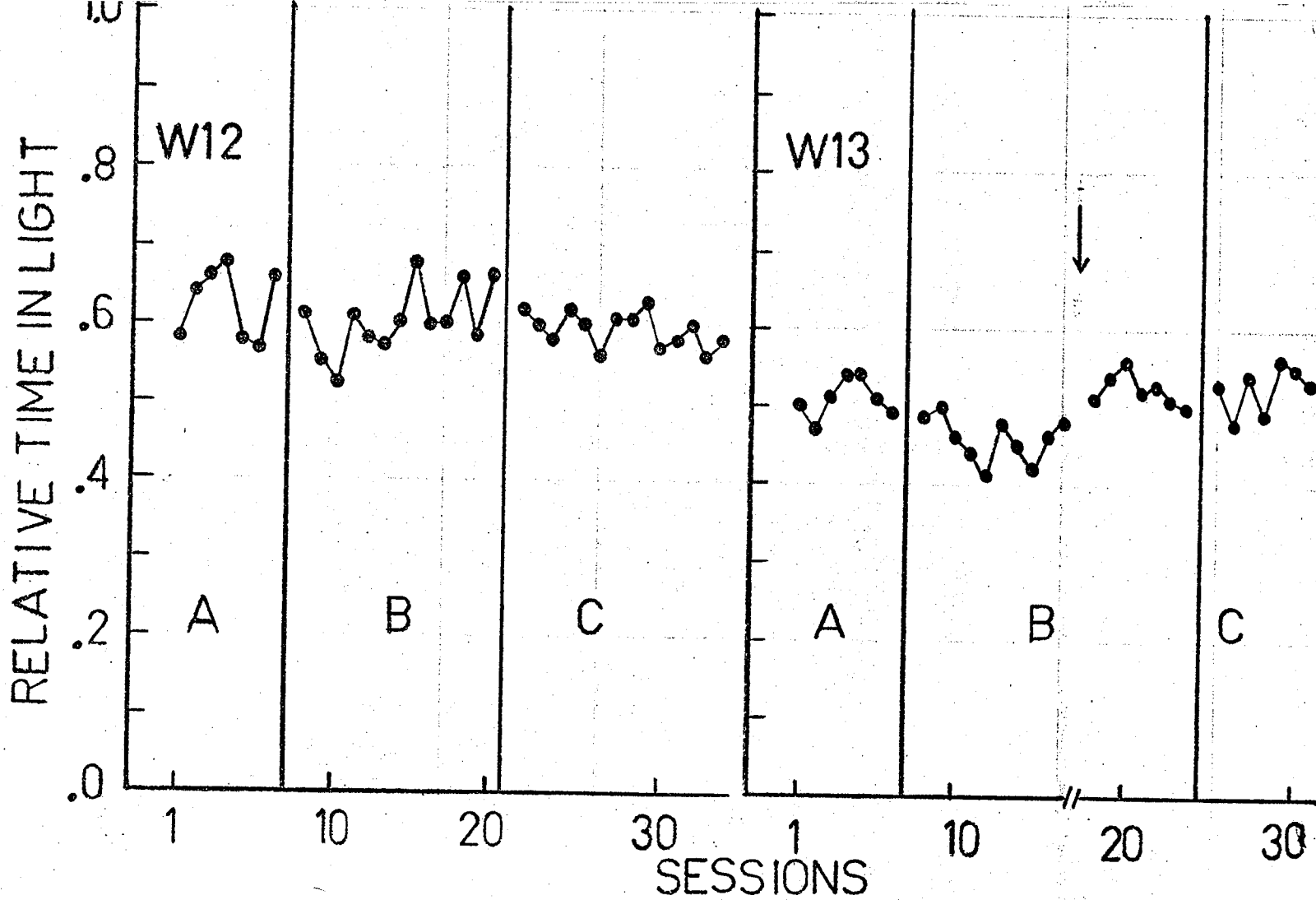


Figure 10. The relative amount of time spent in the light stimulus by subjects W12 and W13. Panel A shows the last 7 sessions on concurrent VI 60 sec VI 60 sec. Panel B shows the sessions on concurrent VI 60 sec VI 60 sec. The arrow indicates where subject W13 was reinforced for not responding for three sessions. These sessions are omitted from the figure. Panel C shows the final sessions on concurrent VI 60 sec VI 60 sec.

subjects showed no marked shift in preference following the introduction of the concurrent VI 60 sec VT 60 sec schedule. This finding was substantiated during the shift from concurrent VI 60 sec VT 60 sec to concurrent VI 60 sec VI 60 sec. The C panel of Figure 10 shows the relative amount of time spent in the presence of the light condition after the subjects were returned to concurrent VI 60 sec VI 60 sec. Again there was no indication of a shift in preference for the light stimulus. The subjects tended to spend about one-half of the session in the light stimulus and about one-half of the session in the dark stimulus.

Discussion

The major finding of the present experiment was that there was no preference for the VI 60 sec schedule while the subjects were on concurrent VI 60 sec VT 60 sec. This finding supports Bloomfield's interpretation of behavioral contrast. It will be recalled that Bloomfield believes that behavioral contrast is due to the shift to a less preferred (or worse) condition in one component of a multiple schedule. Since no behavioral contrast was found on the multiple VI VT schedules in Experiment I, Bloomfield's interpretation of contrast would hold that the shift from multiple VI VI to multiple VI VT did not involve a worsening of conditions. This being the case, the subjects should show no preference for the VI schedule in a situation in which both VI and VT schedules were available to the subjects. This is what was observed in the present experiment: the subjects showed indifference between the VI and VT schedules while on concurrent VI VT.

3. Summary.

In Experiment I subjects were exposed to multiple schedules in which one component was always a VI schedule. The second component of the multiple schedule was, at various times during the experiment, either (a) a VI schedule, (b) a VT schedule in which reinforcements were delivered independently of responding, or (c) Extinction. The rate of responding in the second component was reduced by both the VT and Extinction schedules. Behavioral contrast was observed, however, only when Extinction was programmed in the second component. The results show that a reduced rate of responding in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast.

The findings of Experiment I support a reinforcement rather than a response rate interpretation of behavioral contrast. Experiment II demonstrated, however, that the findings of Experiment I can also be accounted for by Bloomfield's interpretation of behavioral contrast which suggests that contrast results from the shift to a worse (or less preferred) condition in one component of a multiple schedule. Since the subjects in Experiment II showed no preference for a VI schedule in a concurrent VI VT choice situation, no behavioral contrast on the multiple VI VT schedules would be predicted.

CHAPTER III SOME EXPERIMENTS INVOLVING DELAYED REINFORCEMENT

1. Experiment III. Delayed reinforcement in a multiple schedule.

The experiments reported in Chapter II suggested that a decreased rate of responding in one component of a multiple schedule is not a sufficient condition for the occurrence of behavioral contrast. The experiments reported in this Chapter sought to determine if a reduced rate of responding in one component of a multiple schedule is a necessary condition for the occurrence of behavioral contrast. To provide a clear demonstration that a reduction in response rate is not a necessary condition for the occurrence of behavioral contrast, two conditions must be met. First, the rate of responding in one component of a multiple schedule must increase over its baseline level as a result of some change in the other component. Second, there must be no reduction in the rate of responding in that other component. The present experiment also sought to determine if a reduced frequency of reinforcement in one component of a multiple schedule is necessary to produce behavioral contrast. To demonstrate that a reduction in reinforcement frequency is not a necessary condition for the occurrence of behavioral contrast, it must be shown that any increase in the rate of responding in one component of a multiple schedule is not due to a reduction in reinforcement frequency in the other component.

In an attempt to satisfy these conditions, brief delays of reinforcement were introduced in one component of a multiple schedule. A short value of delay was chosen so as to minimize the likelihood that the introduction of the delayed reinforcement would lead to large decreases in either response or reinforcement rates in the delay

component of the multiple schedule. The present experiment was, for the most part, a preliminary experiment which attempted to determine if delayed reinforcement would (1) produce behavioral contrast in the non-delay component, and (2) involve little, if any, changes in response or reinforcement rates in the delay component.

Method

Subjects. Four adult male albino rats, obtained from the Holtzman Co., served. Subjects 102 and 103 were experimentally naive. Subjects 39 and 40 had previously served in an experiment involving variable-interval reinforcement. Subjects 102 and 103 were 106 days of age at the start of the experiment; the other two subjects were 168 days old. The subjects were reduced to 80 % of their normal free feeding body weights by food deprivation. The subjects' 80 % weights were adjusted, on the basis of data from Ezinga and Becker (in press), to control for normal growth during the period of the experiment. The subjects were maintained at 80 % normal body weight by milk obtained during experimental sessions and by supplements of Purina rat food. The subjects had free access to water in their home cage. The water in the home cage contained oxytetracycline hydrochloride (Terramycin) on about two-thirds of the experimental days.

Apparatus. The experimental space was a standard operant conditioning chamber similar to that used in Experiment II. The chamber contained a response lever requiring a force of about 16.5 grams (0.162 N) to operate, a 7 watt houselight, and a dipper feeder (Lehigh Valley Electronics Model 1351). Reinforcement consisted of 0.01 ml of a mixture of sweetened condensed milk and water (50 % of each by volume).

Experimental events and contingencies were programmed with solid state digital logic. A BRS-Foringer Precision Probability Unit was used to generate the random-interval schedule used in the experiment.

Procedure. Following a short period of preliminary training during which lever pressing was conditioned, subjects 102 and 103 were placed on a multiple schedule of random-interval⁵ reinforcement. The average theoretical inter-reinforcement interval in each component of the multiple schedule was 25 seconds (RI 25 sec). The components of the multiple schedule were correlated with light and darkness in the experimental space. Each component lasted 256 seconds. Six presentations of each component comprised a session. The components were presented in strict alternation with the initial component in each session being varied across days.

After 12 sessions on the multiple RI 25 sec RI 25 sec schedule, delayed reinforcement was introduced in the first component (C1) of the multiple schedule. During C1 (housetlight on) the reinforcement cycle, which previously consisted of the dipper being lowered into a reservoir of milk and then being immediately raised into a receptacle where the subject could drink, was changed so as the dipper remained lowered in the reservoir for a period of 5 seconds. Responding during the delay period between the dipper descent and the dipper ascent had no programmed consequences. No exteroceptive stimulus was correlated with the delay period. Reinforcements in the other component (C2) continued to be delivered without the delay interval.

⁵ A random-interval schedule is one in which reinforcements are assigned randomly in time. Millenson (1963) gives a more complete description of random-interval schedules.

Following 9 sessions in which C1 reinforcements were delayed by 5 seconds, the subjects received an additional 14 sessions without the delay period in C1.

The procedure for subjects 39 and 40 was similar to that of subjects 102 and 103 except for the omission of preliminary training and the number of sessions received during a particular condition. Summary details of the procedure for these subjects, as well as for subjects 102 and 103, are presented in Table 3.

Table 3

Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule		Number of sessions			
Reinforcement in		102	103	39	40
C1	C2				
A. Immediate	Immediate	12	12	18	16
B. 5 Sec Delay	Immediate	9	9	10*	12*
C. Immediate	Immediate	14	14	13	13

* Subjects 39 and 40 were not run for 7 consecutive days between the 7th and 8th sessions in this condition.

With the exception noted in Table 3, the subjects received either 6 (subjects 102 and 103) or 7 (subjects 39 and 40) sessions each week. Experimental sessions occurred at about the same time each day.

Results

Figure 11 shows, for the different subjects, the rate of responding in each component of the multiple RI 25 sec RI 25 sec schedule before, during, and after the introduction of the 5 second delay of reinforcement in C1. Panel A shows the rate of responding in C1 and C2 of the multiple schedule during the last 6 sessions of pre-

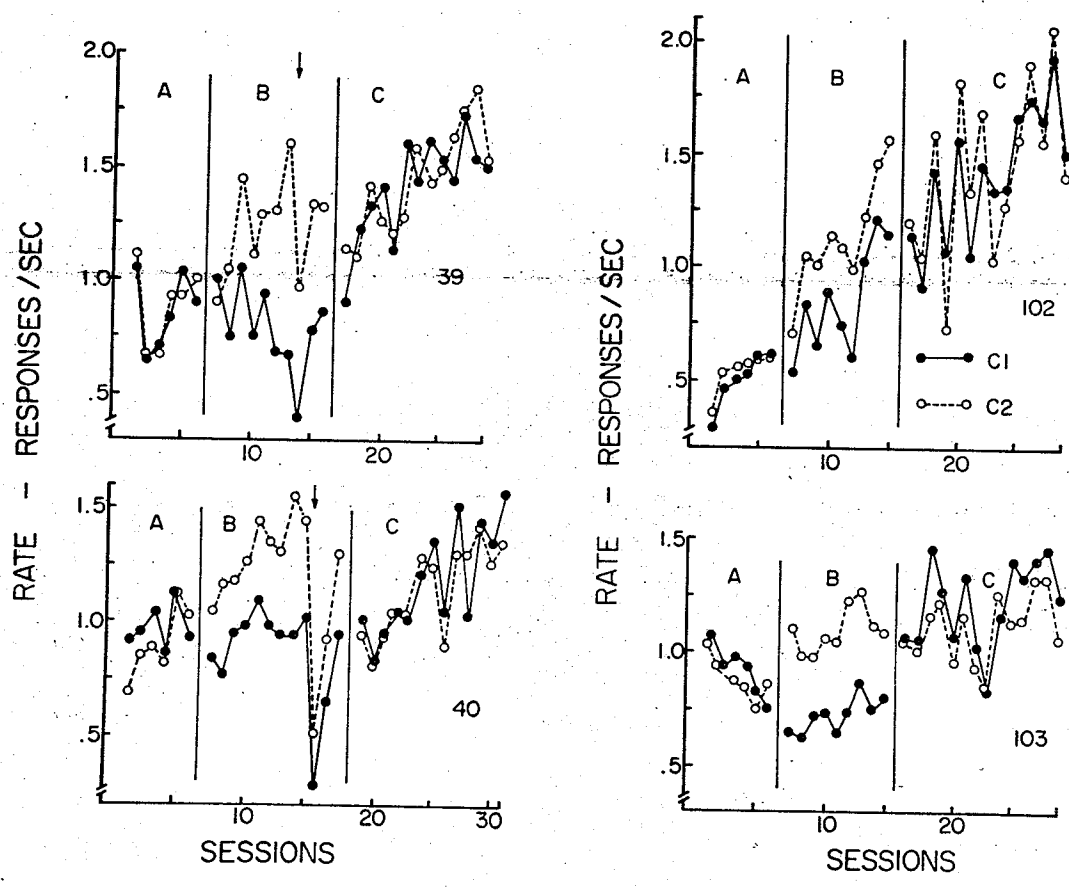


Figure 11. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subjects 39, 40, 102, and 103. Panel A shows the last 6 sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which reinforcement in C1 was delayed by 5 seconds. Panel C shows the final sessions in which reinforcement in both components was immediate. The arrows indicate where subjects 39 and 40 were not run for a one-week period.

liminary training in which there was no delay of reinforcement in C1. These sessions were used as a baseline against which to assess the effects produced by the introduction of delayed reinforcement in C1. No systematic differences in the rate of responding in the two components of the multiple schedule can be seen at this stage.

The middle (B) panels of Figure 11 shows the rate of responding in each component of the multiple schedule after the 5 second delay of reinforcement was introduced in C1. The rate of responding in the non-delay component (C2) is of particular interest here. The rate of responding appeared to increase over its previous level when delayed reinforcement was introduced in C1. Whether this increase in C2 response rate was a case of behavioral contrast or merely the continuation of trends established during the previous baseline condition is not entirely clear for subjects 39 and 40. However, the data for the other two subjects is more suggestive that the observed rate increase in C2 was behavioral contrast. The data for subject 103, in particular, suggest that the rate increase in C2 was behavioral contrast resulting from the introduction of delayed reinforcement in C1 since the increased rate in C2 was a complete reversal of the baseline trend.

Response rate during the delayed reinforcement component is also shown in Figure 11. In computing response rate in C1 during the delayed reinforcement condition neither the delay time nor responses during the delay period were subtracted. Computing response rate in this manner tends to underestimate the actual rate in this component if the subject did not respond or responded less frequently during the delay interval. Since casual observation indicated that the subjects did

respond only occasionally during the delay interval, the computed rate of responding in C1 is actually a conservative estimate of the actual response rate in this component. Given this bias in the C1 response rate it is still apparent that the introduction of delayed reinforcement in C1 did not reduce the rate of responding in this component for all of the subjects. Subject 102 showed an increased, rather than a decreased, rate of responding in the delayed reinforcement component. The response rate for subject 40 did not appear to be decreased. Subject 39 is less clear. Only subject 103 showed a clear decrease in C1 response rate. These considerations suggest that the increase in C2 response rate did not result from a reduction in the rate of responding in the delay component in all cases.

The increase in C2 response rate during the delayed reinforcement condition did not appear to be the result of a decreased frequency of reinforcement in C1 of the multiple schedule. Figure 12 shows the total number of reinforcements obtained in each component of the multiple schedule for the three phases of the experiment. There is little evidence that C1 reinforcement frequency decreased below that in C2 when delayed reinforcement was introduced in C1 (panel B). The rather large amount of variation in the total number of reinforcements obtained in both components during all three phases of the experiment was probably due to the fact that reinforcements were assigned with a probability unit rather than the convention punched tape used on variable-interval schedules.

When the subjects were returned to the original schedule, all subjects showed a temporary decrease in C2 response rate (C panel of

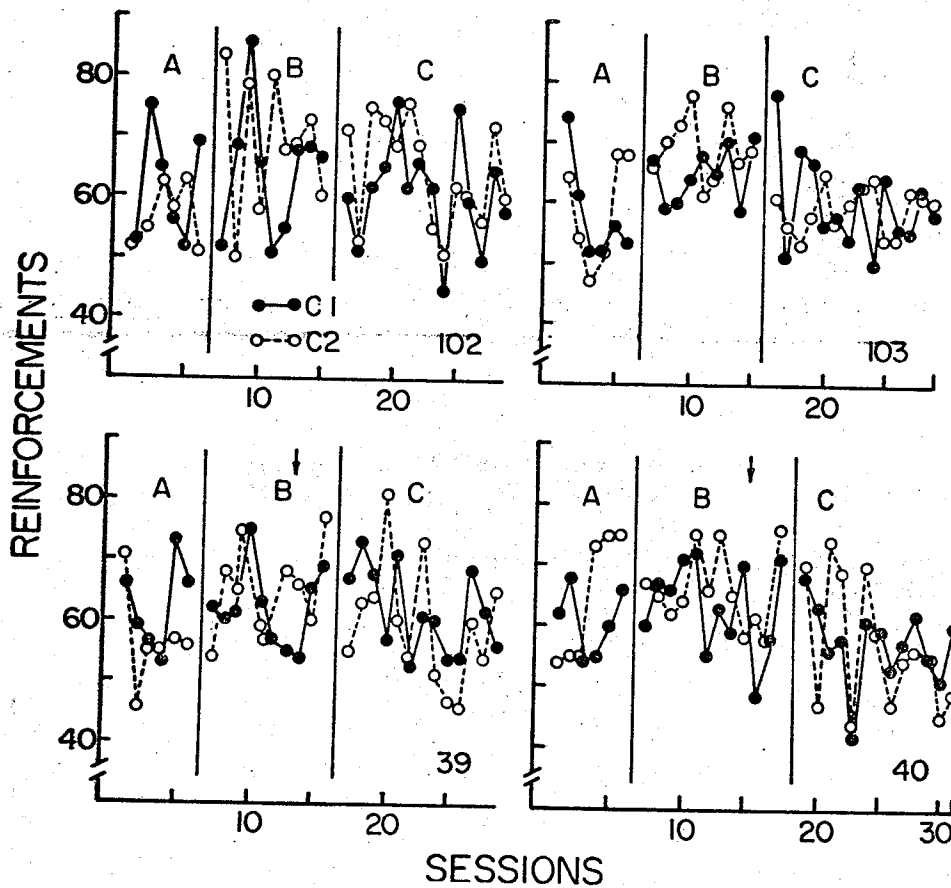


Figure 12. The total number of reinforcements obtained in both components of the multiple RI 25 sec RI 25 sec schedule. Panel A shows the last 6 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcement was delayed by 5 seconds. Panel C shows the final sessions in which reinforcement in both components was immediate. The arrows indicate where subjects 39 and 40 were not run for a one-week period. Data are for subjects 39, 40, 102, and 103.

Figure 11). No subject, however, returned to its original C2 baseline level of responding. Response rate during both C1 and C2 tended to level off at the C2 rate of the delayed reinforcement condition (subjects 40 and 103) or increase above the C2 rate prevailing during the delayed reinforcement condition (subjects 39 and 102).

Discussion

While it is fairly clear that the increased rate of responding observed in C2 during the delayed reinforcement condition did not result from a decrease in C1 response rate or from a decrease in the number of reinforcements obtained in C1, it is not perfectly clear whether the increased rate of responding observed in C2 was a genuine case of behavioral contrast resulting from the introduction of the delayed reinforcement in the C1 component or merely the continuation of baseline trends. Interpretation of the rate increase in C2 is made more difficult by the fact that the original baseline rates of responding were not recoverable after exposure to the delayed reinforcement condition. Had the rate rate of responding in C2 returned to the original baseline level, a stronger case for behavioral contrast could have been made. There are some lines of evidence that suggest that behavioral contrast may not always be reversible. In several experiments conducted in our laboratory it has been frequently found that behavioral contrast is not reversible (e.g. Pear and Wilkie, 1969). Similar findings have been observed in an experiment by Bloomfield (1967).

Granted the limitations of the present experiment, perhaps the

safest conclusion is that the introduction of delayed reinforcement in one component of a multiple schedule may produce behavioral contrast in the other component. If the rate increase observed in the non-delay component of the present experiment was behavioral contrast, it would appear that neither a reduced rate of responding nor a reduced rate of reinforcement in one component of a multiple schedule may be necessary to produce behavioral contrast.

2. Experiment IV. A second experiment with delayed reinforcement in a multiple schedule.

The present experiment attempted to provide additional information on the effect of delayed reinforcement in a multiple schedule. The experiment was essentially a replication, with different subjects, of Experiment III. The experiment attempted to overcome some of the limitations found in Experiment III. For example, an attempt was made to obtain stabler baselines in the present experiment than were obtained in Experiment III. Also, responses made during the delay interval were recorded. These and the time taken by the delay interval were used to calculate an accurate rate of responding in the delay component.

Method

Subjects. Three adult male albino rats, obtained from the Holtzman Co., served. The subjects were experimentally naive and ranged in age from 109 to 138 days of age at the start of the experiment. The subjects were reduced to 80 % normal free feeding body weight by food deprivation. The subjects' 80 % weights were adjusted to control for normal growth on the basis of data from Ezinga and Becker (in press).

The subjects were maintained at 80 % normal body weight by milk obtained during experimental sessions and by supplements of Purina rat food. The subjects had free access to water in the home cage. The home cage water contained oxytetracycline hydrochloride (Terramycin) on about two-thirds of the experimental days.

A female homing pigeon also served. This subject had served previously in Experiment I. The bird was maintained at 80 % normal body weight by a grain mixture obtained during experimental sessions.

Water and grit were continuously available in the home cage.

Apparatus. The apparatus used for the rat subjects was the same as used in Experiment III. The apparatus used for the pigeon was the same as used in Experiment I.

Procedure. After a short period of preliminary training, the rats were placed on a multiple RI 25 sec RI 25 sec schedule. Reinforcement in both components was immediate. The components were correlated with light and darkness in the experimental space. Components lasted 256 seconds and were presented in strict alternation.

After several sessions (see Table 4 for details) on multiple RI 25 sec RI 25 sec, the rats were shifted to a multiple RI 25 sec RI 25 sec schedule in which reinforcements in the first component (C1) were delayed by a period of 5 seconds. The procedure for delaying reinforcement was the same as used in Experiment III. Responding during the delay interval was recorded but had no programmed consequences.

Summary details of the procedure for the rat subjects are presented in Table 4.

Table 4

Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule		Reinforcement in			
		C1	C2	Number of sessions	
			P99	W6	W11
A.	Immediate	Immediate	46	22	20
B.	5 Sec Delay	Immediate	21	18	14

The pigeon (P3) was first placed on a multiple VI 1 min VI 1 min schedule. Reinforcement, which consisted of 4 seconds access to a grain mixture, was immediate in both components of the multiple schedule. The components, which were 5 minutes in duration, were correlated with a red or blue-green light projected on the rear of the response key. The components occurred in strict alternation throughout the session.

After 12 sessions on multiple VI 1 min VI 1 min with immediate reinforcement in both components, the bird was placed on a multiple VI 1 min VI 1 min schedule in which reinforcements in the blue-green component (C1) were delayed. Reinforcement was delayed in the following manner. The first peck after a VI reinforcement assignment started a clock which ran for a fixed period of time, When this clock finished running, a second clock, which operated the grain feeder, was started. During the operation of both clocks the stimulus on the response key was extinguished. Key pecking during the delay interval was recorded but had no programmed consequences. The value of the delay period was varied in different sessions in an attempt to maintain the rate of responding in the delay component at about the same level as was occurring during the baseline condition. The value of delay used

during the 10 sessions in which delayed reinforcement was in force was as follows: 5,3,3,1,1,1,2,3,3, and 3 seconds. During these sessions, reinforcement in the red component (C2) were delivered immediately following a key peck.

Sessions for the pigeon consisted of 6 presentations of each component. Sessions for the rat subjects consisted of 5 presentations of each component. Seven sessions per week were given. Sessions occurred at about the same time each day. Sessions began in either C1 or C2 which varied across sessions.

Results

Panel A of Figures 13 to 16 shows the rate of responding in both components of the multiple schedule during the last 14 (P99, W6, and W11) or last 11 (P3) sessions in which reinforcement in both components was delivered immediately after a response. Unlike the comparable data in Experiment III, there appeared to be no trends in the response rates during the baseline phase of the present experiment. Also it is evident that there is no differential rate of responding in the two components of the multiple schedule.

Panel B of Figures 13 to 16 shows the rate of responding in both components for the sessions in which reinforcement in C1 was delayed. Two measures of response rate are shown for the delay component. The first, which will be called the uncorrected rate of responding, was computed in a manner similar to that used in Experiment III. That is, the total number of responses in the delay component was divided by the total time the delay component was in effect. This measure is shown by the black circles connected by the solid lines.

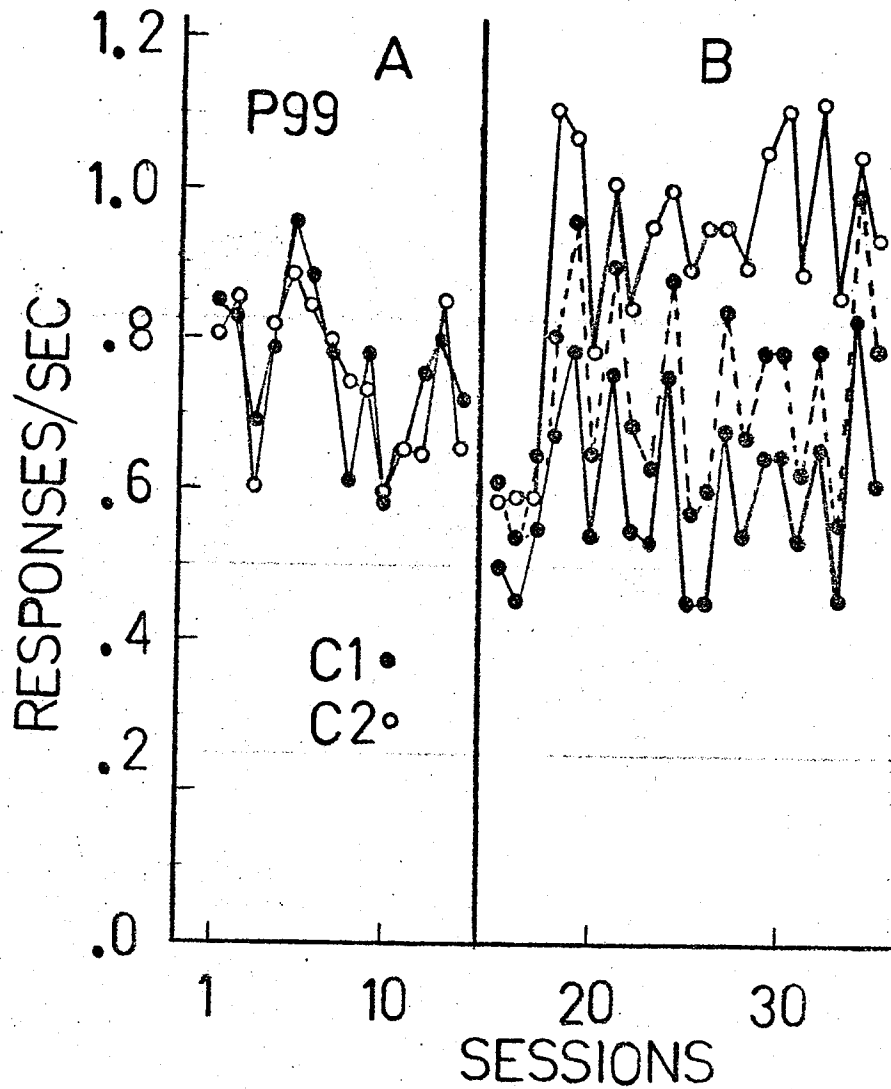


Figure 13. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject P99. Panel A shows the last 14 sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which reinforcement in C1 was delayed by 5 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (○---○) response rate.

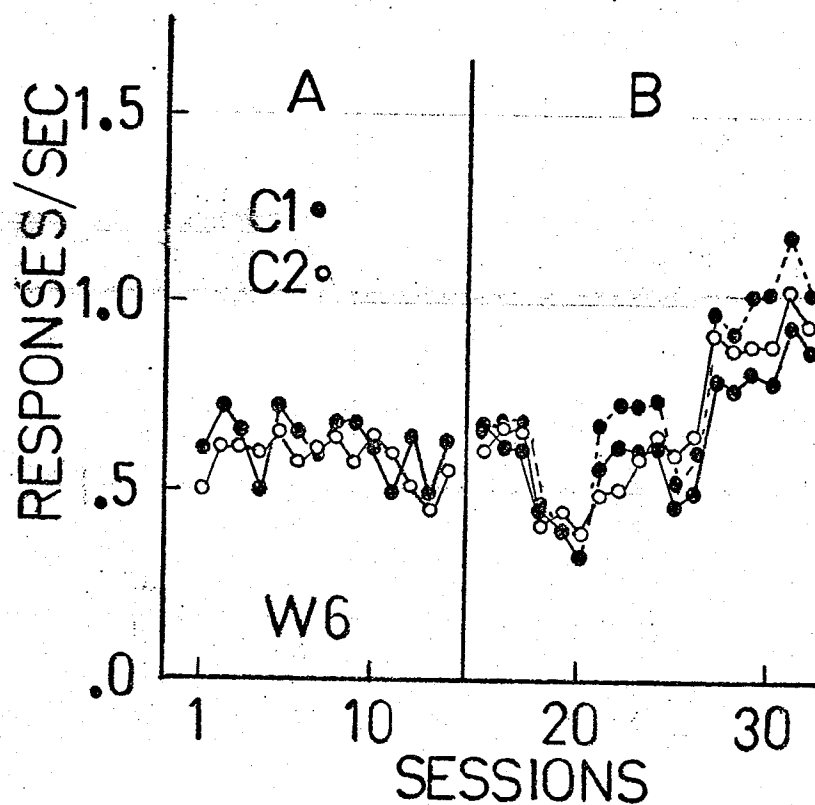


Figure 14. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W6. Panel A shows the last 14 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcement was delayed by 5 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (●- - -●) response rate.

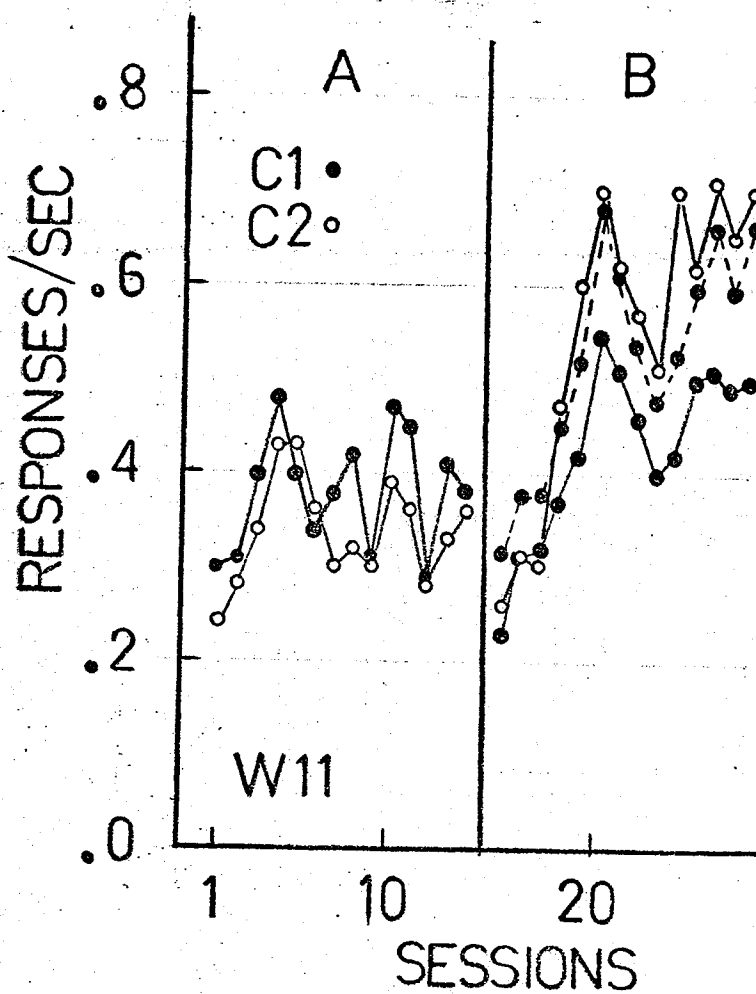


Figure 15. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W11. Panel A shows the last 14 sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which C1 reinforcement was delayed by 5 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (○---○) response rate.

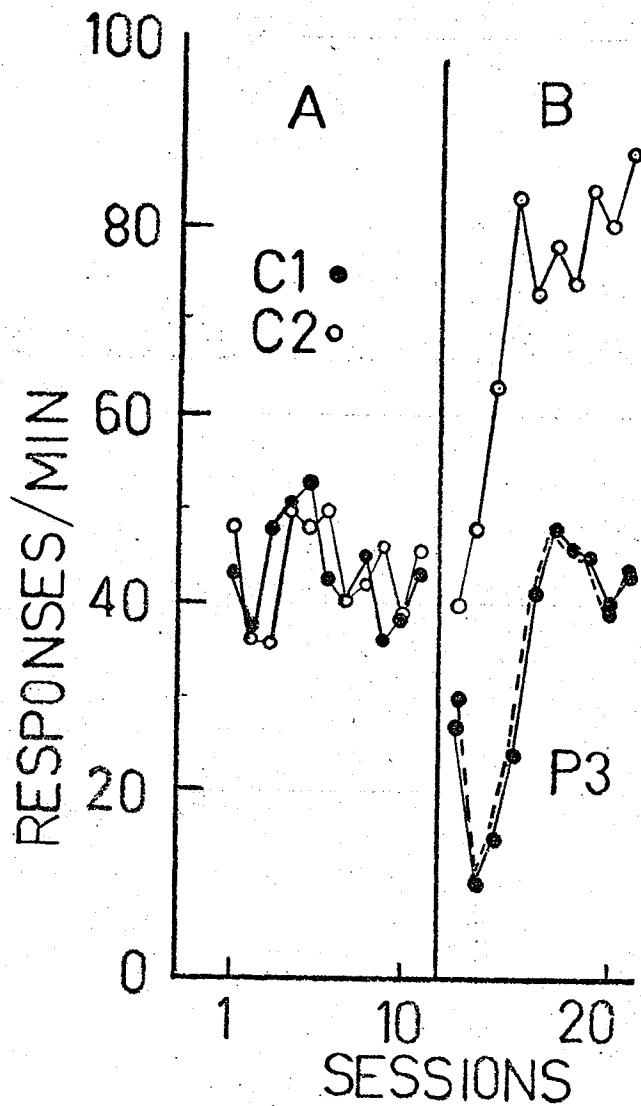


Figure 16. The rate of responding, in responses per minute, in both components of the multiple VI 1 min VI 1 min schedule. Panel A shows the last 11 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcement was delayed. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (○---○) response rate. Data are for subject P3.

The second measure of response rate, called the corrected response rate, is shown by the black circles connected by the broken lines. This response rate measure was computed in the following manner -

corrected response rate =

$$\frac{\text{total responses in delay component} - \text{responses in delay interval}}{\text{total time in delay component} - \text{total delay time}}$$

This measure subtracted out both responses occurring during the delay interval and the time reinforcement was delayed to yield a measure of response rate that is more comparable to the response rate measure in the non-delay component.

The introduction of delayed reinforcement in C1 was followed by an increased rate of responding in C2 for all subjects. This effect occurred within the first few sessions for all subjects except W6. This subject's rate of responding in C2 did not increase until 12 sessions after the introduction of the delayed reinforcement in C1. The fact that the C2 rate did not increase sooner raises doubts about whether W6's rate increase in C2 was directly related to the introduction of delayed reinforcement. However, it should be noted that this subject responded quite often during the delay interval during the early sessions of the delayed reinforcement condition. While subjects P99 and W11 averaged about 0.05 responses per second in the delay interval, subject W6 responded at about 0.23 responses per second during the first 12 sessions of the delay condition. During the last 6 sessions of the delay condition, W6's rate of responding in the delay interval had dropped to about 0.10 responses per second. The fact that the C2 rate of responding did not increase during the

first 12 sessions of the delay schedule could have been due to a lack of exposure to delayed reinforcement caused by responding during the delay period.

The increased rate of responding observed in the C2 component did not appear to be generally correlated with decreases in response rate in the delay component. This is especially true if one considers the corrected, rather than the uncorrected, response rate in the delay component. Only for the pigeon did the introduction of delayed reinforcement lead to a large decrease in C1 response rate. However, the decrease for this subject was only temporary. When the delay interval was shortened from its initial value of 5 seconds, the response rate in C1 increased. The response rate in C1 for this subject during the last 6 sessions of the delayed reinforcement condition was approximately equal to the baseline rate. The data for the other subjects also suggests that the increased rate of responding observed in the non-delay component was not due to decreases in response rate in the delay component. The rate in C1 increased for subjects W6 and W11. The rate in C1 for subject P99 remained at about the same level as during the baseline condition. Thus the rate of responding in C2 of the multiple schedule increased regardless of whether the rate of responding increased (W6 and W11), decreased temporarily (P3), or remained about the same (P99) in C1 after delayed reinforcement was introduced in this component.

The increased rate of responding observed in C2 did not appear to be the result of a reduced frequency of reinforcement in C1. The

number of reinforcements obtained in both components for both phases of the experiment is shown in Figure 17. Panel A of Figure 17 shows the number of reinforcements obtained in both components when reinforcement in both components was immediate, Panel B shows the number of reinforcements obtained during sessions in which reinforcement in C1 was delayed. There appeared to be little, if any, difference in the number of reinforcements obtained in the delay and non-delay components for P3. The data for the other subjects is not as clear, but if fewer reinforcements were obtained in the delay component, the difference was small and not consistent on a session-to-session basis.

Discussion

The results of this experiment support the tentative conclusion reached in Experiment III that the introduction of delayed reinforcement in one component of a multiple schedule produces behavioral contrast in the other, non-delay, component. The results of the present experiment are considerably clearer in this regard than those of Experiment III. While some of the increases in response rate in the non-delay component in Experiment III could be interpreted as continuations of baseline trends rather than behavioral contrast, the results of the present experiment suggest that the increase in rate of responding in the non-delay component was behavioral contrast resulting from the introduction of delayed reinforcement in the other component.

Again, as in Experiment III, there is some evidence to suggest that the increased rate of responding observed in the non-delay

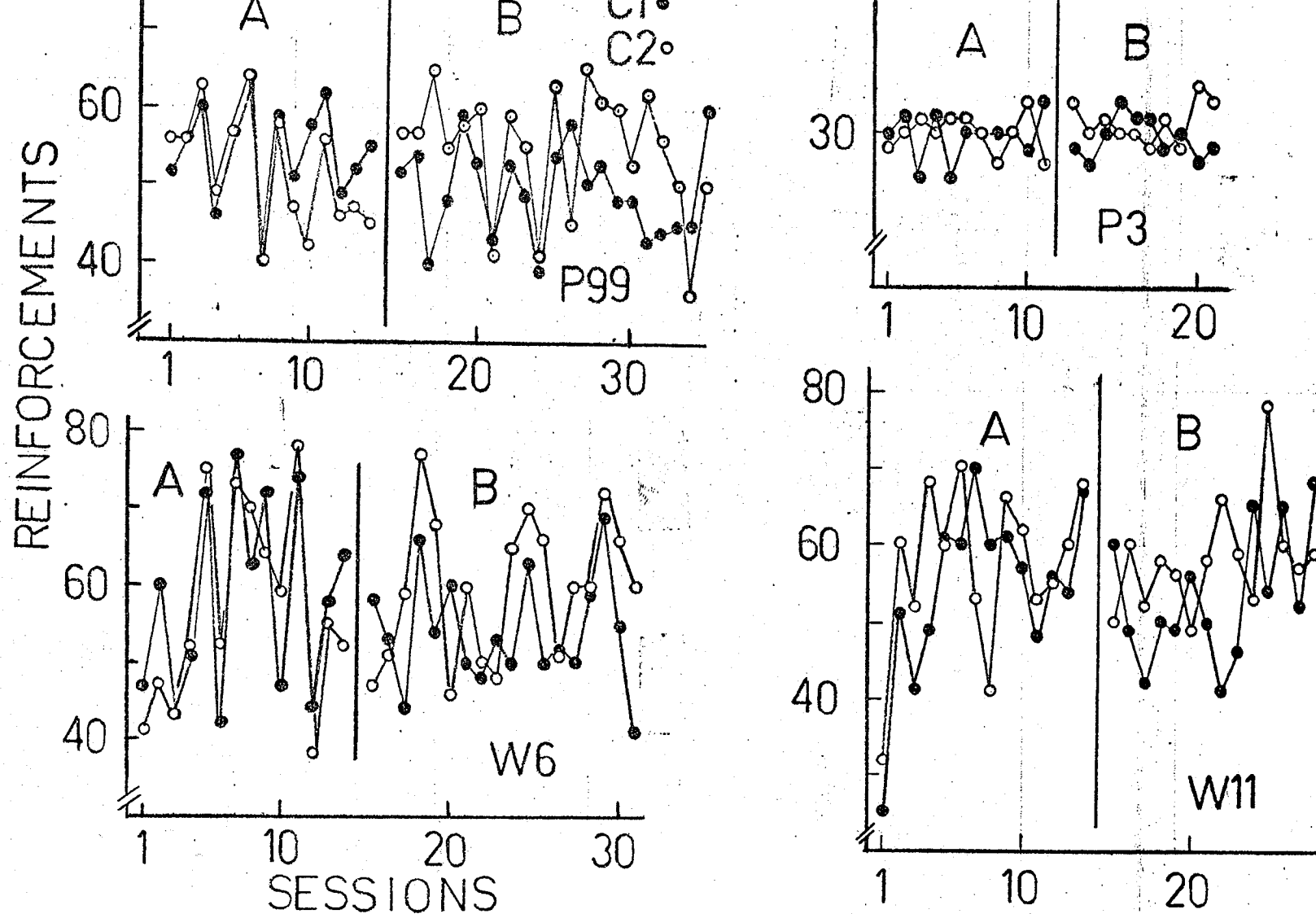


Figure 17. The number of reinforcements obtained in each component of the multiple RI 25 sec RI 25 sec (subjects P99, W6, and W11) and multiple VI 1 min VI 1 min (subject P3) schedules. Panel A shows the last 14 (11 for P3) sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcements were delayed.

component was not a result of a reduction in response or reinforcement rate in the delay component. The occurrence of the increased rate of responding in the non-delay component appeared to be independent of response rate in the delay component. The rate of responding in the non-delay component increased after the introduction of the delayed reinforcement regardless of whether there was little or no change, a temporary decrease, or an increase in the rate of responding in the delay component. Similarly, there is some evidence to suggest that the increased rate of responding in the non-delay component did not result from a reduction in reinforcement frequency in the delay component. The data for subject P3 are suggestive in this regard. The data for the other subjects is less clear, but if the frequency of reinforcement in the delay component was less than that in the non-delay component, the difference between the two components was small and not consistent on a session-to-session basis. Also in this regard, it should be noted that similar differences sometimes existed during the baseline condition, yet this did not lead to behavioral contrast. Thus while the possibility is not eliminated entirely, there is some evidence to suggest that the rate of responding increase in the non-delay component did not depend upon a reduction in reinforcement frequency.

3. Experiment V. A third experiment with delayed reinforcement in a multiple schedule.

This experiment was another replication of Experiment III. A longer delay interval was used for two of the three subjects. The

three rats from Experiment IV served.

Method

Subjects. Subjects P99, W6, and W11 served.

Apparatus. The experimental chamber as well as the programming and recording equipment was identical to that of Experiment IV.

Procedure. Immediately following the completion of Experiment IV, the subjects were placed on a multiple RI 25 sec RI 25 sec schedule in which reinforcement in both components was immediate. After several sessions with immediate reinforcement in both components, the subjects were shifted to a multiple RI 25 sec RI 25 sec schedule in which reinforcement in the first component was delayed by either 5 (subject P99) or 10 (subjects W6 and W11) seconds. Summary details of the procedure are shown in Table 5.

Table 5

Summary of Procedure: Multiple RI 25 sec RI 25 sec Schedule		Number of sessions			
Reinforcement in		P99	W6	W11	
	C1				
A.	Immediate	Immediate	14	21	22
B.	Delayed	Immediate	14	14	21

Other aspects of the procedure (e.g. delay procedure, component duration, session length, etc.) were similar to that of Experiment IV.

Results

Figures 18, 19, and 20 show the rate of responding in both components of the multiple RI 25 sec RI 25 sec schedule during both

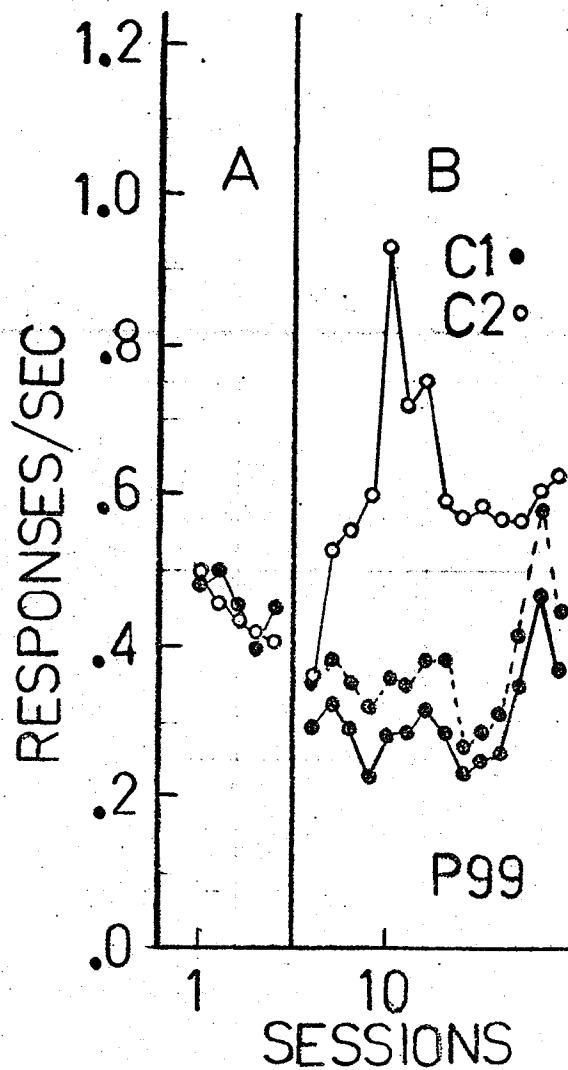


Figure 18. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Panel A shows the last 5 sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which C1 reinforcement was delayed by 5 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (●- -●) response rate. Data are for subject P99.

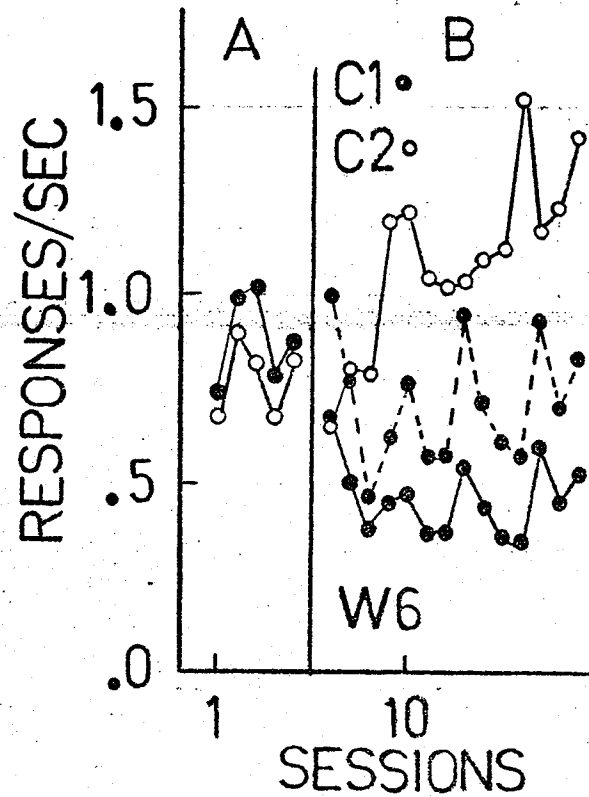


Figure 19. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Data are for subject W6. Panel A shows the last 5 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcement was delayed by 10 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (●---●) response rate.

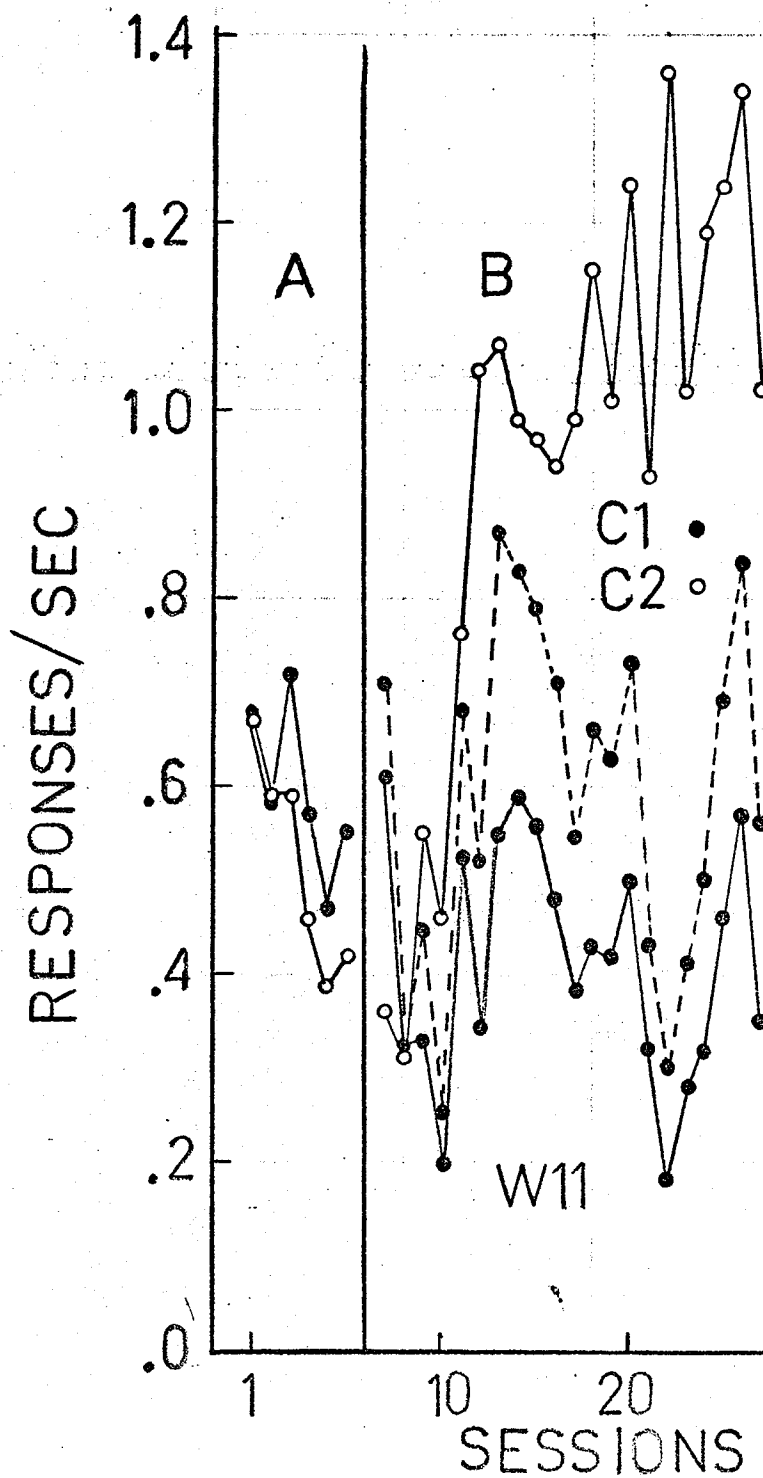


Figure 20. The rate of responding, in responses per second, in both components of the multiple RI 25 sec RI 25 sec schedule. Panel A shows the last 5 sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which C1 reinforcement was delayed by 10 seconds. Two response rate measures are shown for C1 during the delayed reinforcement condition - uncorrected (●—●) and corrected (○- - -○) response rate. Data are for subject W11.

phases of the experiment. Panel A of these figures shows the rate of responding in the two components during the last 5 sessions of baseline conditions. Panel B shows the rate of responding in both components for the sessions in which C1 reinforcements were delayed. As can be seen from these figures, all three subjects showed an increase in C2 response rate following the introduction of delayed reinforcement in C1. This rate increase appeared soon after the introduction of the delayed reinforcement in C1. The fact that W6 showed an increased rate soon after the introduction of the delayed reinforcement is interesting in view of the results for this subject in Experiment IV. It will be recalled that this subject showed an increased response rate some 12 sessions after the introduction of delayed reinforcement in that experiment. It was suggested that this result might have been due to the fact that this subject tended to respond frequently during the delay interval. This explanation is supported by the present experiment. Subject W6 responded infrequently (about 0.06 responses per second) in the delay interval in the present experiment. This finding suggests that the increased rate of responding observed in the non-delay component of the multiple schedule is related to a suppression of responding (and a exposure to an actual delay of reinforcement) in the delay interval.

The rate of responding in the delay component is also shown in Figures 19 to 20. The corrected rate of responding in C1 did not appear to be reduced by the delayed reinforcement for subject W11. The rate of responding in C1 for the other two subjects did

show an overall decrease following the introduction of the delayed reinforcement. (During several of the delayed reinforcement sessions, however, the corrected rate of responding in the delay component was about the same as it was during the baseline condition.)

The number of reinforcements obtained in both components of the multiple schedule is shown in Figure 21. Panel A shows the last 5 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcements were delayed. The number of reinforcements obtained in the delay component appeared to be consistently lower than the number obtained in the non-delay component. The difference in reinforcement frequency in the two components was not consistent, however, on a session-to-session basis.

Discussion

The present experiment replicated the major finding of the earlier delayed reinforcement experiments, viz., that the introduction of delayed reinforcement in one component of a multiple schedule produces behavioral contrast in the other, non-delay, component. All three subjects in the present experiment showed an increased rate of responding in the non-delay component after the introduction of delayed reinforcement. It is interesting to note that subject W6 showed a more-or-less immediate increase in response rate in the non-delay component following the introduction of delayed reinforcement in the present experiment. This finding suggests that a suppression of responding during the delay interval, such as occurred for this subject

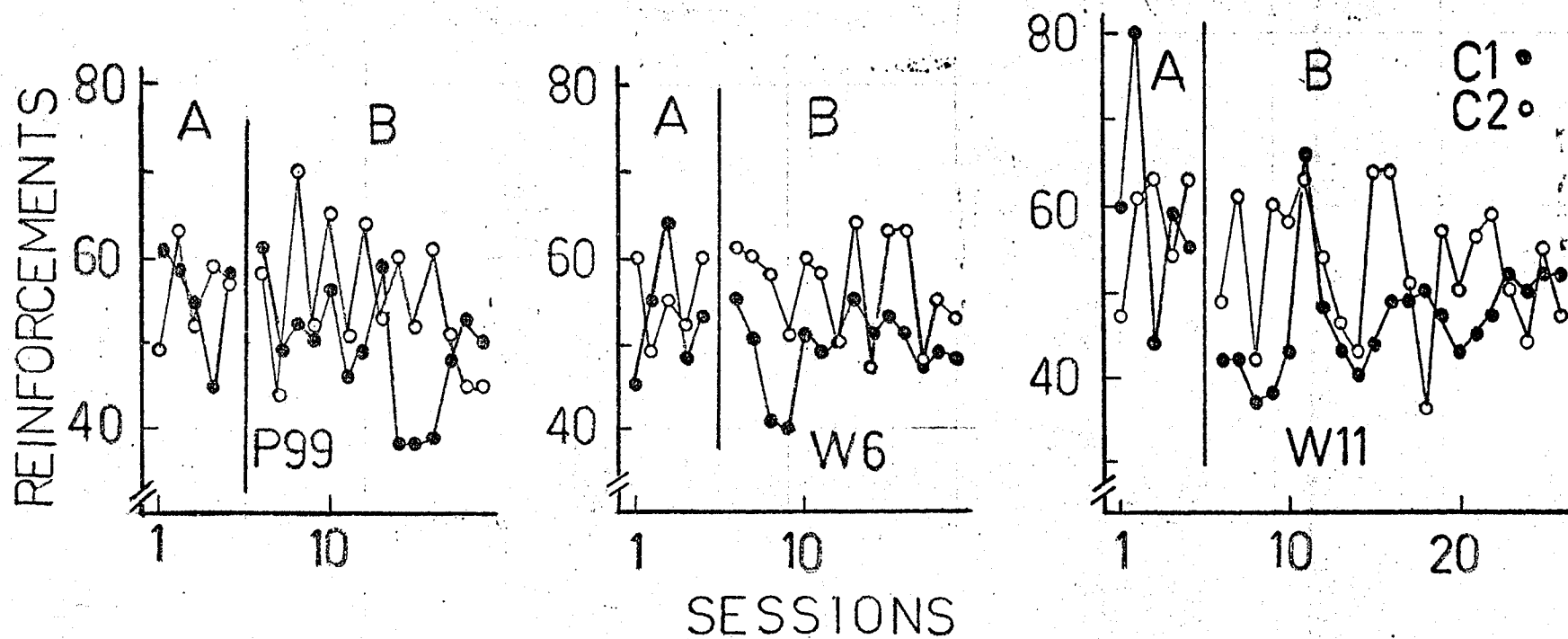


Figure 21. The total number of reinforcements obtained in each component of the multiple RI 25 sec RI 25 sec schedule. Panel A shows the last 5 sessions in which reinforcement in both components was immediate. Panel B shows the sessions in which C1 reinforcement was delayed by either 5 (subject P99) or 10 (subjects W6 and W11) seconds.

in the present experiment, is a necessary prerequisite for the occurrence of behavioral contrast in the non-delay component of the multiple schedule. Since responding during the delay interval has the effect of shortening the delay interval between response and reinforcement, a suppression of responding during the delay interval ensures that the subject is being exposed to the delay of reinforcement. This fact could explain why subject W6 showed an immediate increase in response rate in the present experiment and a slower increase in Experiment IV. This problem would probably not have been encountered had responding during the delay interval postponed the delivery of reinforcement. This technique would have ensured a constant delay period between responses and reinforcement.

While the evidence is considerably weaker than in Experiment IV, there is some evidence in the present experiment which suggests that a reduction in response rate in one component of a multiple schedule is not a necessary prerequisite for the occurrence of behavioral contrast. This is that the response rate in the non-delay component increased for subject W11 after the introduction of delayed reinforcement in spite of the fact that there was no consistent decrease in the corrected response rate in the delay component for this subject. There is little evidence in the present experiment to suggest that the contrast observed was not due to a reduction in reinforcement frequency in the delay component of the multiple schedule. The number of reinforcements obtained in the delay component appeared to be generally lower than the number obtained in the non-delay component. This decrease in reinforcement frequency in the delay component for W6 and W11 is

not surprising considering the length of the delay interval (10 seconds) and the average interreinforcement interval (25 seconds) used in the present experiment. The decrease in reinforcement frequency in the delay component for subject P99 was probably attributable to the low rate of responding in the delay component shown by this subject.

The results of the present, as well as the previous, delayed reinforcement experiments tend not to completely support the rate of responding hypothesis of behavioral contrast. The data of Experiment IV, in particular, suggest that a reduction in the rate of responding in one component of a multiple schedule is not a necessary condition for the occurrence of behavioral contrast. The data for subject 102 in Experiment III and subject W11 in the present experiment also suggest that behavioral contrast may occur in situations where response rate in one component of a multiple schedule is not decreased. There is also some evidence in these experiments to suggest that a reduction in reinforcement frequency in one component of a multiple schedule is also not a necessary prerequisite for the occurrence of behavioral contrast. The data of the present experiment are not clear in this regard. However, the data of the previous experiments, in particular the data of subject P3 in Experiment IV, suggest that a reduced frequency of reinforcement in one component of a multiple schedule may not be necessary for the occurrence of behavioral contrast.

The findings of the present and previous delayed reinforcement experiments are quite consistent with Bloomfield's interpretation of behavioral contrast which views contrast as resulting from the shift

to a less preferred (or worse) condition in one component of a multiple schedule. It is known (e.g. Chung, 1965; Chung and Herrnstein, 1967) that organisms prefer immediate to delayed reinforcement. This being the case, the shift from immediate to delayed reinforcement in the present experiments would, on the basis of Bloomfield's hypothesis, be expected to produce behavioral contrast. This, of course, was what was observed.

4. Summary.

Subjects were first trained on a two-component multiple schedule in which reinforcement in both components was delivered immediately after a response. Reinforcement was scheduled on equal RI or VI schedules in the two components. Following training with immediate reinforcement in both components, reinforcement in one component of the multiple schedule was delayed by a few seconds. The major effect of the delayed reinforcement was to increase the rate of responding in the non-delay component of the multiple schedule. This contrast effect did not appear to be dependent upon a reduction in the rate of responding or the frequency of reinforcement in the delay component in all cases.

The delayed reinforcement experiments suggest that a reduction in response and/or reinforcement rate in one component of a multiple schedule may not be a necessary condition for the occurrence of behavioral contrast in all cases. The results are, however, quite compatible with Bloomfield's hypothesis which holds that behavioral contrast is the result of a worsening of conditions in one component of a multiple schedule.

CHAPTER IV DISCUSSION1. The necessary and sufficient conditions for the occurrence of behavioral contrast.

It will be recalled from Chapter I that there are three major accounts of what constitutes necessary and sufficient conditions for the occurrence of behavioral contrast. These are (1) a reduced rate of responding in one component of a multiple schedule, (2) a reduced frequency of reinforcement in one component of a multiple schedule, and (3) a worsening of conditions in one component of a multiple schedule. The findings of the present research suggest that a reduction in response rate in one component of a multiple schedule is neither a necessary nor sufficient condition for the occurrence of behavioral contrast. The results for the multiple VI VT schedules in Experiment I show that a reduction in response rate in one component of a multiple schedule by itself is not a sufficient condition for the occurrence of behavioral contrast. Behavioral contrast was found in the delayed reinforcement experiments reported in Experiments III, IV, and V despite the fact that there was no general decrease in response rate in the delay component. This finding suggests that a reduced rate of responding in one component of a multiple schedule may not be a necessary prerequisite for the occurrence of behavioral contrast. These experiments also suggest that a reduced frequency of reinforcement in one component of a multiple schedule may not be a necessary prerequisite for the occurrence of behavioral contrast. Contrast was found in the non-delay component despite the fact that there was little, if any, decrease in the rate of reinforcement in the delay component for at

least some of the subjects. These data tend to limit the generality of both the rate of responding and rate of reinforcement interpretations of behavioral contrast.

The data of the present experiments provide a considerable degree of support for Bloomfield's hypothesis regarding the determinants of behavioral contrast. It will be recalled from Chapter I that Bloomfield's hypothesis, which holds that behavioral contrast results from a worsening of conditions in one component of a multiple schedule, accounts for a considerable amount of the experimental evidence that has been used to support the rate of responding and frequency of reinforcement interpretations of behavioral contrast. The generality of this hypothesis is increased by the present research. First, the failure to find behavioral contrast on the multiple VI VT schedules in Experiment I is compatible with Bloomfield's hypothesis since another experiment (Experiment II) demonstrated that rats do not prefer VI over VT schedules. This being the case one could conclude that the shift from VI to VT did not involve a shift to a worse or less preferred condition and that behavioral contrast would not be expected to occur under these conditions. Second, the occurrence of behavioral contrast in the delayed reinforcement experiments could be said to result from a shift to a worse or less preferred condition in one component of a multiple schedule. The shift from immediate to delayed reinforcement could be considered as a worsening of conditions since it is known (e.g. Chung, 1965) that animals prefer immediate as opposed to delayed reinforcement in a concurrent situation.

The findings of the present research suggest then, that the

major determinants of behavioral contrast in multiple schedules is the change to a worse or less preferred condition in one component. A worsening of conditions appears to be a sufficient and necessary condition for the occurrence of behavioral contrast. This hypothesis of behavioral contrast appears to be more general than the response or reinforcement rate hypotheses of contrast. In addition to accounting for a considerable number of experimental findings, Bloomfield's hypothesis has another advantage. This is that it makes possible an integration of several aspects of multiple and concurrent performances. Such an integration would appear desirable when one considers the similarities of multiple and concurrent schedules. Concurrent schedules, particularly those programmed with a changeover-key technique, can be considered as multiple schedules in which the subject, rather than the experimenter, controls the components (cf. Catania, 1966). Since Bloomfield's hypothesis predicts that any change to a non-preferred condition will result in behavioral contrast, findings from concurrent preference studies can be used to predict whether or not a particular change in one component of a multiple schedule would be expected to produce behavioral contrast. The converse, prediction of preference in a concurrent situation on the basis of whether or not behavioral contrast was observed in multiple schedules, is also a possibility.

In conclusion, it would appear that Bloomfield's hypothesis of behavioral contrast is the most general of the current hypotheses of behavioral contrast. Just how general a hypothesis it is, is an empirical question. It is also an empirical question if this hypothesis can account for some of the other effects, such as the peak

shift, that typically occur during the establishment of stimulus control over operant behavior.

2. Some considerations concerning the definition of behavioral contrast.

The data reported in this paper, in particular those from the delayed reinforcement experiments, are relevant to the problem of defining behavioral contrast. Behavioral contrast has typically been defined as a change in response rate in one component of a multiple schedule in a direction opposite the change in either response rate (Reynolds, 1961a) or reinforcement frequency (Bloomfield, 1967) in the other component. It is obvious that all of the increases in response rate observed in the delayed reinforcement experiments would not, according to these definitions, be considered as instances of behavioral contrast. While it is true that the rate of responding did increase in one component of a multiple schedule after the introduction of delayed reinforcement in the other component, there was not a general decrease in either response or reinforcement rate in the delay component in all cases. This consideration points out a difficulty with the above definitions of behavioral contrast, namely, that they are more of an explanation than a definition of behavioral contrast. Defining contrast as a rate change in one component of a multiple schedule in a direction opposite the change in response or reinforcement rate in that component logically implies that contrast is dependent upon such changes. This problem has been recognized by Bloomfield (1969) who has suggested that behavioral contrast be regarded as simply " an uncalled for change in responding

in one component of a multiple schedule" (P. 219). To this could be added, for the sake of clarity, "as a result of some change in conditions in another component". This definition appears to encompass quite well the types of effects observed in the delayed reinforcement experiments. In addition, this definition also has the advantage of incorporating the essential feature of the traditional definition, namely, a change in the rate of responding in one component of a multiple schedule, while at the same time not specifying in advance the types of changes in the other component that will produce such rate changes. This definition, however, fails to specify the direction of rate change involved in behavioral contrast. Presumably, a decrease in response rate in one component of a multiple schedule (which is typically called "negative behavioral contrast" or "negative induction" #see Reynolds (1961a)) would be considered as behavioral contrast. One could get around this problem by defining behavioral contrast as an uncalled for increase in response rate in one component of a multiple schedule. This formulation, however, is also incomplete. For example, Reynolds (1961b) has found that the shift from multiple Extinction Extinction to multiple VI Extinction produces an increase in response rate in the Extinction as well as the VI component of the multiple schedule. The increased rate in the Extinction component would, according to the above definition, be considered as behavioral contrast. Such a rate increase, however, would not be typically considered as a case of behavioral contrast.

These and similar considerations encountered in attempting to define behavioral contrast suggest that defining behavioral

contrast, at this stage, may be premature. It may be better to talk about specific, empirically established response rate changes in multiple schedules without attaching labels to such rate changes until the causes - ie. necessary and sufficient conditions - of these changes have been empirically well established.

REFERENCES

- Amsel, A., and Roussel, J. Motivational properties of frustration: I. Effect on a running response of the addition of frustration to the motivational complex. Journal of Experimental Psychology, 1952, 43, 363-368.
- Azrin, N.H., and Holz, W.C. Punishment. In W.K. Honig (Ed.) Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 380-447.
- Bloomfield, T.M. Behavioral contrast and relative reinforcement frequency in two multiple schedules. Journal of the Experimental Analysis of Behavior, 1967, 10, 151-158.
- Bloomfield, T.M. Behavioural contrast and the peak shift. In R.M. Gilbert and N.S. Sutherland (Eds.) Animal discrimination learning. New York: Academic Press, 1969. Pp. 215-241.
- Brethower, D.M., and Reynolds, G.S. A facilitative effect of punishment on unpunished behavior. Journal of the Experimental Analysis of Behavior, 1962, 5, 191-199.
- Brownstein, A.J., and Hughes, R.G. The role of response suppression in behavioral contrast: Signaled reinforcement. Psychonomic Science 1970, 18, 50-52.
- Brownstein, A.J., and Newsom, C. Behavioral contrast in multiple schedules with equal reinforcement rates. Psychonomic Science, 1970, 18, 25-26.
- Catania, A.C. Behavioral contrast in multiple and concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 335-342.
- Catania, A.C. Concurrent operants. In W.K. Honig (Ed.) Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 213-270.
- Chung, S.H. Effects of delayed reinforcement in a concurrent situation. Journal of the Experimental Analysis of Behavior, 1965, 8, 439-444.
- Chung, S.H., and Herrnstein, R.J. Choice and delay of reinforcement. Journal of the Experimental Analysis of Behavior, 1967, 10, 67-74.
- Ezinga, G., and Becker, G. Is hunger drive held constant in the behavior experiment employing a fixed food-deprivation schedule? Psychological Reports, in press.

- Fantino, E. Effects of required rates of responding upon choice. Journal of the Experimental Analysis of Behavior, 1968, 11, 15-22.
- Findley, J.D. Preference and switching under concurrent scheduling. Journal of the Experimental Analysis of Behavior, 1958, 1, 123-144.
- Gilbert, R.N. Discrimination learning? In R.N. Gilbert and N.S. Sutherland (Eds.) Animal discrimination learning. New York: Academic Press, 1969, Pp. 455-489.
- Hanson, H.M. Effects of discrimination training on stimulus generalization. Journal of Experimental Psychology, 1959, 58, 321-334.
- Honig, W.K., Boneau, C.A., Burstein, K.R., and Pennypacker, H.S. Positive and negative generalization gradients obtained after equivalent training conditions. Journal of Comparative and Physiological Psychology, 1963, 56, 111-116.
- Hull, C.L. A behavior system. New Haven: Yale University Press, 1952.
- Jenkins, H.M. Generalization gradients and the concept of inhibition. In D.I. Mostofsky (Ed.) Stimulus generalization. Stanford: Stanford University Press, 1965. Pp. 55-61.
- Millenson, J.R. Random interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1963, 6, 437-443.
- Nevin, J.A., and Shettleworth, S.J. An analysis of contrast effects in multiple schedules. Journal of the Experimental Analysis of Behavior, 1966, 9, 305-315.
- Nevin, J.A. Differential reinforcement and stimulus control of not responding. Journal of the Experimental Analysis of Behavior, 1968, 11, 715-726.
- Pavlov, I.P. Conditioned reflexes. (Translated by G.V. Anrep) London: Oxford University Press, 1927.
- Pear, J.J., and Wilkie, D.M. Stimulus change as a discriminative event in a semimultiple schedule. Proceedings of the Seventy-Seventh Annual Convention of the American Psychological Association, 1969, 797-798.
- Ratliff, F., Hartline, H.K., and Miller, W.H. Spatial and temporal aspects of retinal inhibitory interaction. Journal of the Optical Society of America, 1963, 53, 110-120.
- Rescorla, R.A., and Skucy, J.C. Effect of response-independent reinforcers during extinction. Journal of Comparative and Physiological Psychology, 1969, 67, 376-380.

- Reynolds, G.S. Behavioral contrast. Journal of the Experimental Analysis of Behavior, 1961a, 4, 57-71.
- Reynolds, G.S. An analysis of interactions in a multiple schedule. Journal of the Experimental Analysis of Behavior, 1961b, 4, 107-117.
- Reynolds, G.S., and Limpo, A.J. On some causes of behavioral contrast. Journal of the Experimental Analysis of Behavior, 1968, 11, 543-547.
- Spence, K.W. The nature of discrimination learning in animals. Psychological Review, 1936, 44, 430-444.
- Stubbs, D.A., and Pliskoff, S.S. Concurrent responding with fixed relative rate of reinforcement. Journal of the Experimental Analysis of Behavior, 1969, 12, 887-895.
- Terrace, H.S. Discrimination learning with and without errors. Journal of the Experimental Analysis of Behavior, 1963, 6, 1-27.
- Terrace, H.S. Stimulus control. In W.K. Honig (Ed.) Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 271-344.
- Terrace, H.S. Discrimination learning, the peak shift, and behavioral contrast. Journal of the Experimental Analysis of Behavior, 1968, 11, 727-741.
- Weisman, R.G. Some determinants of inhibitory stimulus control. Journal of the Experimental Analysis of Behavior, 1969, 12, 443-450.
- Weisman, R.G. Determinants of inhibitory stimulus control. Paper read at the Thirty-First Annual Convention of the Canadian Psychological Association, Winnipeg, Manitoba, 1970.
- Yarczower, M., Gollub, L.R., and Dickson, J.F. Some effects of discrimination training with equated frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 415-423.
- Zeiler, M.D. Fixed and variable schedules of response-independent reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 405-414.

Appendix

A Methodological Note Concerning Rate of Responding ⁶

The basic datum in operant conditioning experiments is typically rate of responding. This measure is generally expressed as an average rate of responding over a particular interval. The choice of an interval over which to average response rate is important in two respects. First, the interval should be short enough so that an effect may be observed. For example, one would not choose an interval of several hours over which to average response rate if the effect was expected to last only a few minutes. Effects observed are thus to a degree dependent upon the time interval over which we choose to average response rate. Second, the time interval should be long enough so that an effect is not obscured by short-term fluctuations in rate of responding. One would not typically use an interval of one minute over which to average response rate since minute-to-minute fluctuations in rate of responding would tend to be large in most experiments and would tend to obscure an effect, especially if the effect was small.

The choice of an actual interval over which to average response rate is largely an empirical matter. The main criterion for choosing an interval is the orderliness of the resulting data. Any interval which yields orderly data can be considered appropriate.

Once a time interval has been chosen, an average rate of responding for this interval can be computed. This is done simply by dividing the total number of responses which occurred in the interval by the amount

6. This note concerns the rate of responding measures plotted in Figures 2, 3, 4, 5, 6, 7, 8, 11, 13, 14, 15, 16, 18, 19, and 20.

of time in the interval. The actual time unit used is an arbitrary matter. One could divide the number of responses in the interval by the number of seconds in the interval to yield an average rate of responding expressed in responses per second or one could divide by the number of minutes in the interval to yield an average rate of responding expressed in responses per minute and so forth. One could convert, without distorting the data, one average response rate to another simply by dividing or multiplying by an appropriate constant. For example, one could convert an average rate expressed in responses per minute to an average rate expressed in responses per second by dividing the former by 60.

For the sake of convenience both average responses per minute and average responses per second were used in the present experiments. However, in all cases the time interval over which response rate was averaged was the same, viz, one complete daily session. Session duration varied somewhat between subjects and experiments but was constant for any subject throughout an experiment. In any event, the major comparisons in the present research were within rather than between subjects. For any given subject, both the rate of responding shown (either responses per second or responses per minute) and the period of time over which this response rate was averaged was constant throughout an experiment.