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DELAYED REINFORCEMENT IN A MULTIPLE SCHEDULE[1]

DONALD M. WILKIE

UNIVERSITY OF MANITOBA

Three rats and a pigeon were first trained on a two-component multiple schedule in which reinforcement in the two components occurred immediately after a response. Later, reinforcement in one component was delayed by a few seconds. During both stages of the experiment, reinforcement was scheduled by equal variable- (pigeon) or random-interval (rats) schedules in the two components. The main effect of the delayed reinforcement was to increase the rate of responding in the unchanged (non-delay) component. This behavioral contrast effect did not appear in all cases to be dependent upon a reduction in the rate of responding or the frequency of reinforcement in the delay component. This finding suggests that a reduction in response rate and/or reinforcement frequency in one component of a multiple schedule may not be a necessary prerequisite for the occurrence of behavioral contrast. This finding is, however, consistent with an explanation that suggests that behavioral contrast results from the introduction of a less-preferred condition in one component of a multiple schedule, since it is known that animals "prefer" immediate to delayed reinforcement.

The establishment of stimulus control in a multiple schedule through differential reinforcement is sometimes accompanied by an increased rate of responding during the component correlated with reinforcement. This increased rate of responding has been called "behavioral contrast" (Reynolds, 1961). A considerable amount of research has been 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 stimulus control is established without "errors" (responses during the component associated with non-reinforcement) behavioral contrast is not observed (Terrace, 1966). One necessary prerequisite, then, for the occurrence of behavioral contrast appears to be responding during the component associated with non-reinforcement.

Given that non-reinforced responding does occur during the establishment of stimulus control, what other conditions are necessary for the occurrence of behavioral contrast? It has been suggested that behavioral contrast results from either (1) a reduction in the frequency of reinforcement (Reynolds, 1961), or (2) a reduction in the rate of responding (Terrace, 1966) during one component of a multiple schedule. A clear choice between these two accounts of behavioral contrast is still not possible. Several experiments (*e.g.*, Brethower and Reynolds, 1962; Terrace, 1968; Reynolds and Limpo, 1968; Weisman, 1969; Brownstein and Huges, 1970; Brownstein and Newsom, 1970) have implicated a reduced rate of responding as the prerequisite for the occurrence of contrast. Other experiments (*e.g.*, Reynolds, 1961; Catania, 1961; Bloomfield, 1967; Nevin, 1968) have supported the frequency of reinforcement account of contrast.

An as yet unexamined possibility is that *neither* a reduced rate of responding nor a re-

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duced frequency of reinforcement during one component of a multiple schedule is a necessary condition for the occurrence of behavioral contrast. The experiment reported here attempted to examine this possibility. To demonstrate that a reduction in response or reinforcement rate in one component of a multiple schedule is not a necessary condition for the occurrence of behavioral contrast, two conditions must be met: (1) the rate of responding in one component of a multiple schedule must increase over its baseline rate as a result of some change during the other component; (2) there must be no reduction in the rate of responding or frequency of reinforcement in the changed component. Previous unpublished pilot work by the author has suggested that these conditions might be met by the introduction of brief delays of reinforcement in one component of a multiple schedule. In the present experiment, subjects were first trained on a two-component multiple schedule in which reinforcement in both components was immediate. Later, delayed reinforcement was introduced in one component.

METHOD

Subjects

Three adult male albino rats, obtained from the Holtzman Co., 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 and maintained at 80% normal body weight by food deprivation. The 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 received oxytetracycline hydrochloride (Terramycin) in their home cage water on about two-thirds of the experimental days. A female adult homing pigeon, obtained locally, also served. The bird had previously served in an experiment involving multiple schedules of reinforcement. The bird was maintained at 80% normal body weight by grain obtained during experimental sessions.

Apparatus

The experimental space used for the rat subjects was a standard operant conditioning chamber (Lehigh Valley Electronics Model 1316). The chamber contained a response lever requiring a force of about 16.5 g (0.162 N) to operate, a 7-w houselight, and a dipper feeder (Lehigh Valley Electronics Model 1351). The reinforcer consisted of 0.01 ml of a mixture of sweetened condensed milk and water (50% of each by volume). Experimental events and contingencies were arranged with solid state digital logic. A BRS-Foringer Precision Probability Unit was used to generate the random-interval schedules used. The experimental space used for the pigeon was a BRS-Foringer Model PS-004 pigeon chamber. On one wall of the chamber was mounted a response key and a grain feeder. Operation of the key required a force of about 20 g (0.196 N). Stimuli were projected on the rear of the response key by an Industrial Electronics Engineers' One Plane Readout Cell. During the 4-sec access to the reinforcer, stimuli on the response key were extinguished and a small light illuminated the grain in the feeder tray. Experimental contingencies and events were arranged with standard relay type equipment. All recording and scheduling equipment were located in a room separate from the rooms containing the experimental spaces. Fans provided ventilation and a partial masking noise in both experimental spaces. Data were recorded on digital impulse counters.

Procedure

After a short period of preliminary training, during which lever pressing was conditioned, the rats were placed on a multiple schedule of random-interval[2] reinforcement. The average theoretical inter-reinforcement interval in each of the two components of the multiple schedule was 25 sec (RI 25-sec). The components of the multiple schedule were correlated with light and darkness in the experimental space. Each component lasted 256 sec, and they were presented in strict alternation. Reinforcement in both components was immediate.

After several sessions (see Table 1 for details) with immediate reinforcement in both components, reinforcement in the first component (C1) was delayed by 5 sec. During

[2]A random-interval schedule is one in which reinforcement is assigned randomly in time. Millenson (1963) gives a more complete description of random-interval schedules.

C1 (houselight 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 that the dipper remained lowered in the reservoir for a period of 5 sec before being raised. Responding during the delay interval between dipper descent and dipper ascent was recorded but had no scheduled consequences. No exteroceptive stimulus was correlated with the delay period. Reinforcement in the other component (C2) continued to occur without delay.

Table 1

Summary of Procedure

	Reinforcement in		*Number of Sessions*			
			Subject			
	C1	*C2*	*P99*	*W6*	*W11*	*P3*
A.	Immediate	Immediate	46	22	20	12
B.	Delayed	Immediate	21	18	14	10

The pigeon (P3) was first placed on a multiple schedule of variable-interval reinforcement. The average inter-reinforcement interval in each of the two components of the multiple schedule was one minute (VI 1-min). Reinforcement was immediate in both components. The components, which were 5 min 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 of immediate reinforcement in both components, reinforcement in the blue-green component (C1) was delayed. Reinforcement was delayed in the following manner. The first peck after a VI reinforcement assignment started a clock that timed for a fixed period. When this time period elapsed, 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 scheduled 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 in the 10 sessions in which delayed reinforcement was in force was: 5, 3, 3, 1, 1, 1, 2, 3, 3, and 3 sec. During these sessions, reinforcement in the red component (C2) occurred immediately on a key peck.

Sessions for the pigeon consisted of six presentations of each component. Sessions for the rats consisted of five presentations of each component. All subjects received seven sessions per week. Sessions occurred at about the same time each day. Sessions began in either C1 or C2, which was varied across sessions.

RESULTS

Panels A of Fig. 1 show the rate of responding in both components of the multiple schedule during the last 14 (Rats P99, W6, and W11) or last 11 (Pigeon P3) sessions in which reinforcement in both components occurred immediately on a response. These sessions were used as a baseline against which to assess the effects produced by the introduction of delayed reinforcement in C1. The B panels of Fig. 1 show the rate of responding in both components for the sessions in which reinforcement in C1 was delayed. Two response rate measures are shown for the delay component (filled or black circles). The first, called the uncorrected rate of responding, was computed in the following manner: the total number of responses emitted during 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 solid lines. The second measure of response rate, called the corrected response rate, is shown by the black circles connected by the broken lines. The latter measure was computed in the following manner: (total responses in delay component – responses in delay interval)/(total time in delay component – delay time). This measure subtracted out both responses during the delay interval and the time reinforcement was delayed and yielded a measure of response rate that was independent of the rate of responding during the delay interval. This corrected response rate provided a means of comparing response rate in C1 during the sessions in which reinforcement was delayed with the sessions in which reinforcement was immediate. Since the subjects tended to respond less frequently during the delay interval, the corrected response

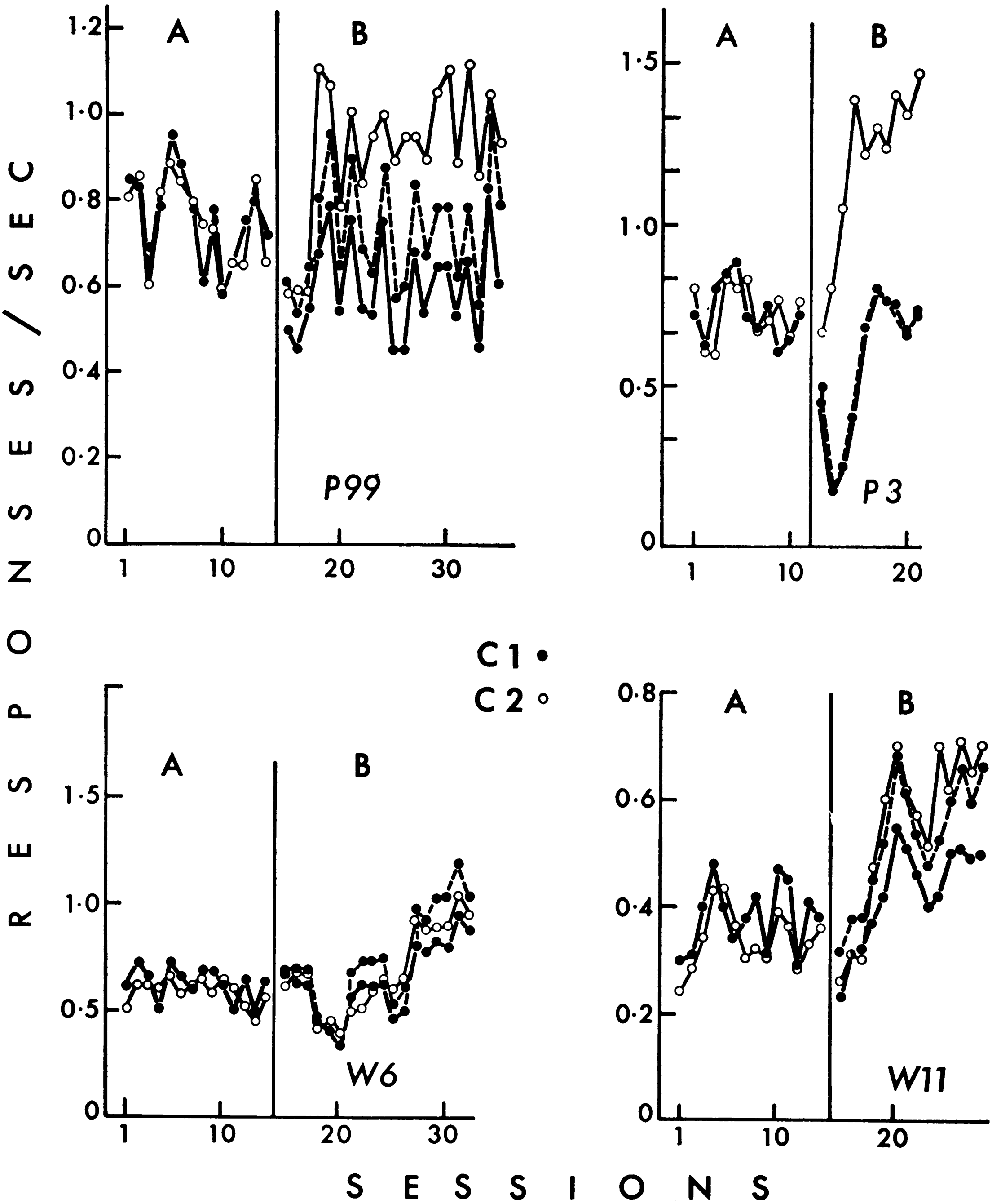

Fig. 1. The rate of responding, in responses per second, in each component of the multiple RI 25-sec RI 25-sec (subjects P99, W6, and W11) and multiple VI 1-min VII 1-min (Subject P3) schedules. Panel A shows the last 14 (last 11 for Subject P3) sessions in which reinforcement was immediate in both components. Panel B shows the sessions in which reinforcement in C1 was delayed. Two response rate measures are shown for C1 during the delayed reinforcement condition—uncorrected (black circles and solid lines) and corrected (black circles and broken lines) response rate. The unfilled circles show response rate during C2, where reinforcement was always immediate.

rate tended to be greater than the uncorrected response rate.

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 after introduction of the delayed reinforcement in C1 for all subjects except W6. This subject's rate of responding in the non-delay component did not increase for about 12 sessions after delayed reinforcement was introduced. The fact that the C2 response rate did not increase sooner raises doubts about whether W6's rate increase in C2 was directly related to introduction of the delayed reinforcement. However, it should be noted that this subject responded quite often during the delay interval during the early sessions of delayed reinforcement. While Subjects P99 and W11 averaged about 0.05 responses per second during the delay interval, W6 responded at about 0.23 responses per second during the first 12 sessions of delayed reinforcement. During the last six sessions of delayed reinforcement, W6's rate of responding in the delay interval dropped to about 0.10 responses per second during the delay period. The fact that the C2 response rate did not increase during the first 12 sessions of delayed reinforcement could have been due to a lack of exposure to the delay in reinforcement caused by responding during the delay period.

The increased rate of responding observed in the C2 component of the multiple schedules did not appear to be correlated with decreases in response rate in the delay component. This is especially true when one considers the corrected, rather than the uncorrected, response rate in the delay component. Only for the pigeon, P3, did the introduction of delayed reinforcement lead to a general decrease in C1 response rate. However, the decrease for this subject was temporary. When the delay interval was shortened from its intial value of 5 sec, the response rate in C1 increased. The rate in C1 during the last six sessions of the delayed reinforcement condition was about equal to the baseline rate. The data for the other subjects also suggest that the rate increase in C2 was not a result of a reduction in C1 rate. The rate of responding in C1 increased after the introduction of the delayed reinforcement in that component for Subjects W6 and W11. Subject P99's rate in C1 remained at about the same level as during the baseline condition. Thus, the rate of responding in the non-delay component of the multiple schedules 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 that component.

The increased rate of responding observed in C2 also did not appear to be the result of a reduced frequency of reinforcement in the delay component in all cases. Table 2 shows the average number of reinforcements obtained per session in each component during both phases of the experiment. Only two of the four subjects (P99 and W6) obtained fewer reinforcements, on the average, in C1 during the sessions in which reinforcement was delayed.

Table 2

The number of reinforcements in each component. Means and standard deviations are based on last 14 (Subjects P99, W6, and W11) or last 11 (Subject P3) sessions with immediate reinforcement in both components and all sessions in which reinforcement in C1 was delayed.

		Mean Number of Reinforcements Obtained per Session		*Standard Deviation*	
Subject	*Reinforcement in C1*	*C1*	*C2*	*C1*	*C2*
P99	Immediate	54.5	51.8	6.3	7.4
	Delayed	49.4	54.6	6.1	8.0
P3	Immediate	29.7	30.0	1.5	1.2
	Delayed	29.7	30.7	1.3	1.3
W6	Immediate	58.1	57.1	12.1	12.6
	Delayed	54.2	59.8	7.1	9.0
W11	Immediate	52.8	57.1	11.4	10.3
	Delayed	54.1	58.2	8.3	7.0

DISCUSSION

The main finding was that the introduction of delayed reinforcement in one component of a multiple schedule produced an increased rate of responding in the component associated with immediate reinforcement.[3] A second finding was that the increased rate of

[3]Similar findings for response latency have been reported by Keller (1970).

responding or behavioral contrast did not appear, in all cases at least, to result from a reduction in response rate in the delay component of the multiple schedule. The lack of correlation between the increased rate of responding in the non-delay component and a reduction in the rate of responding in the delay component of the multiple schedule suggests that a reduction in the rate of responding in one component of a multiple schedule is not a necessary prerequisite for the occurrence of behavioral contrast. Thirdly, there is some evidence in the experiment to suggest that a reduction in the frequency of reinforcement in one component of a multiple schedule is also not a necessary prerequisite for the occurrence of behavioral contrast. This conclusion has also been reached in other experiments (*e.g.*, Terrace, 1968).

The present data do not provide clear support for either the rate of responding or the rate of reinforcement interpretation of the determinants of behavioral contrast. However, the data do appear to support a third interpretation of behavioral contrast. Bloomfield (1969) suggested that behavioral contrast results from the "worsening of conditions" in one component of a multiple schedule. By "worsening of conditions" Bloomfield appears to mean a change in conditions that results in the original condition being preferred (as measured, for example, by time allocation in a concurrent choice situation) to the new condition. Since it is known (*e.g.*, Chung, 1965) that animals prefer immediate to delayed reinforcement in a concurrent situation, the present finding that the introduction of delayed reinforcement in one component of a multiple schedule produces behavioral contrast in the immediate component appears to be quite consistent with Bloomfield's interpretation of the determinants of behavioral contrast.

The present data are also 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, 1961) or reinforcement frequency (Bloomfield, 1967) in the other component. It is obvious that the increases in response rate observed in the present experiment 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 delayed reinforcement was introduced 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 another component logically implies that contrast is dependent upon such changes. This problem was recognized by Bloomfield (1969) who suggested that behavioral contrast be regarded as simply "an *uncalled for* change in responding in one component of a multiple schedule" (p. 219). This definition appears to encompass quite well the type of effects observed in the present experiment. 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 exclude induction effects, which are generally distinguished from contrast effects.

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—*i.e.*, necessary and sufficient conditions—of these changes have been empirically well established.

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