

# BEHAVIORAL CONTRAST WITH FIXED-INTERVAL AND LOW-RATE REINFORCEMENT<sup>1</sup>

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The present experiments demonstrate behavioral contrast with a fixed-interval (FI) and with a DRL<sup>2</sup> schedule of reinforcement: Each schedule maintains a higher rate of responding when it is alternated with a stimulus correlated with extinction than when it is alternated with a stimulus correlated with reinforcement. The occurrence of contrast with these two schedules casts doubt on accounts of contrast that depend on the effects of selective reinforcement or punishment of different inter-response times.

### METHOD

#### *Subjects*

Four experienced, adult, male, White Carneaux pigeons were maintained at 80% of their free-feeding body-weights.

#### *Apparatus*

The experiments were conducted in a standard experimental chamber in the Harvard Laboratory. (See Ferster & Skinner, 1957.) The 0.75-inch translucent key at which the pigeons pecked was operated by a minimal force of about 15 grams. The key was illuminated from behind by orange or blue light. General illumination was provided by two 6-watt lamps. Key pecks were occasionally reinforced with access to mixed grain for 3 seconds through a 2- by 2-inch opening in the wall beneath the key. During reinforcement, the magazine was illuminated, and the other lights were turned off. White noise in the chamber masked extraneous sounds.

#### *Procedure*

Each daily session consisted of 20 (Experiment I) or 15 (Experiment II) cycles of multiple-schedule (mult) reinforcement. Each cycle was 6 minutes: 3 minutes of an orange key followed by 3 minutes of a blue key. The reinforcement schedules associated with each color were varied within each experiment.

*Experiment I: Fixed-interval Contrast.* Table 1 shows the sequence of multiple schedules and the number of sessions for which each was in effect. The schedule during the presentation of orange was either 3-minute, variable-interval (VI 3) or extinction (ext). The schedule during the presentation of blue was either VI 3 or 3-minute, fixed-interval (FI 3).

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<sup>2</sup>Differential reinforcement of low rates of responding: A response is reinforced only if it follows the preceding response by at least *t* seconds.

Table 1  
FI\* Sequence (Birds 68 and 69)

Multiple-schedule Components		Number of Sessions
orange key	blue key	
VI 3	VI 3	15
VI 3	FI 3	25
ext	FI 3	15
VI 3	FI 3	20

\* See text for abbreviations.

When the color of the key changed, variable-interval reinforcements that were programmed but not yet obtained were cancelled. Cancellations were rare. During mult VI 3 VI 3, this procedure was in effect at the change of both key-colors, and the VI schedules were programmed by a single VI tape.

Each 3-minute interval of the FI 3 schedule began with the onset of the blue key. At the end of the 3 minutes, the key remained blue until the reinforced response occurred. This response was almost always emitted less than a second after the 3-minute interval had elapsed.

Responses during successive 30-second intervals in blue were recorded on six counters. The first counter cumulated responses emitted during the first 30 seconds of each 3-minute presentation of blue; the second, responses emitted during the second 30 seconds; and so on. When the schedule associated with blue was FI 3, the successive 30-second intervals corresponded to successive sixths of the 3-minute fixed interval.

Table 2  
DRL\* Sequence (Birds 294, 68, 69, 117)

Multiple-schedule Components		Number of Sessions
orange key	blue key	
DRL 21 sec.	DRL 21 sec.	12
ext	DRL 21 sec.	15
DRL 21 sec.	DRL 21 sec.	12

\* See text for abbreviations.

*Experiment II: DRL Contrast.* Table 2 shows the sequence of schedules and the number of sessions for which each was in effect. These sessions followed 73 sessions of mult DRL 21 sec. (orange) DRL 21 sec. (blue)—a total of 100 sessions of reinforcement on DRL 21 sec. in the presence of blue.

When DRL 21 sec. was programmed, a response was not reinforced when it occurred less than 21 seconds after the preceding response, a change in schedule, or a reinforcement.

When the key was blue, inter-response-time or IRT distributions (Anger, 1956) were obtained. The IRT of a response is the number of seconds elapsed since the previous response. Ten counters provided an IRT distribution in 3-second class intervals. The first counter recorded responses with IRT's of from 0 to 3 seconds; the second, those with IRT's of from 3 to 6 seconds; and so on. Responses recorded in the eighth, ninth, and tenth counters were always reinforced (since they had IRT's greater than 21 seconds). The tenth counter recorded all responses with IRT's greater than 27 seconds.

### RESULTS

The rate of responding maintained by FI or by DRL during the presentation of blue increased when the schedule during the presentation of orange was changed from reinforcement to extinction. In addition,

the terminal rate of responding in the FI 3 exceeded the maintained rate of responding on the VI 3, which provided the same over-all frequency of reinforcement.

#### FI Contrast

Figure 1 shows the average rate of responding during each of the six 30-second intervals after the onset of blue in the last session of each of the procedures. The unfilled circles in Fig. 1a show the VI 3 performance during the presentation of blue in the mult VI 3 VI 3 schedule. The rate of responding was reasonably independent of the time elapsed since the onset of blue. When the schedule during the blue was changed from VI 3 to FI 3, the performance changed to that shown by the filled circles in Fig. 1a. The rate of responding early in the interval, *i.e.*, shortly after the onset of blue (class intervals 1 and 2), declined below the rate maintained by the VI 3 schedule; and the rate just before reinforcement (class intervals 5 and 6) increased above the rate maintained by the VI 3 schedule.<sup>3</sup> If plotted cumulatively, the filled circles would show the average "scallop" maintained during the session by the fixed-interval schedule.

The FI 3 maintained a higher rate when alternated with extinction than when alternated with VI 3. Figure 1b shows the performance on FI 3 after the schedule in orange was changed from VI 3 to extinction (unfilled circles) and after the VI 3 schedule was reinstated (filled circles). The increase is evident throughout the entire fixed interval, except for Pigeon 68 in the sixth class interval.

The magnitude of the rate increase decreased with elapsed time in the fixed interval: It was greatest early in the interval (class intervals 1 to 3) and least just before reinforcement (class intervals 5 and 6). The rate just preceding reinforcement was affected least by the other component of the multiple schedule.

The performance on the original multiple schedule, VI 3 VI 3, was recoverable.

#### DRL Contrast

Figure 2 shows inter-response-time distributions for each pigeon during the presentation of blue. The responses in the last five sessions of each of the three multiple schedules are plotted against the duration of their IRT's in 3-second class intervals: Class interval 1 includes responses with IRT's of from 0 to 3 seconds; class interval 2 includes responses with IRT's of from 3 to 6 seconds; and so on. The abscissa ends at class interval 7 (IRT's of from 18 to 21 seconds) because of the very low frequency of IRT's longer than 21 seconds. This means that Fig. 2 contains only unreinforced responses.

<sup>3</sup>This increase in rate may not be a contrast if the frequency of reinforcement in the presence of the discriminative stimuli in which it occurs is greater than the average frequency in the VI. The increase in reinforcement frequency cannot be calculated because we do not know the discriminative stimuli in the FI nor their durations.

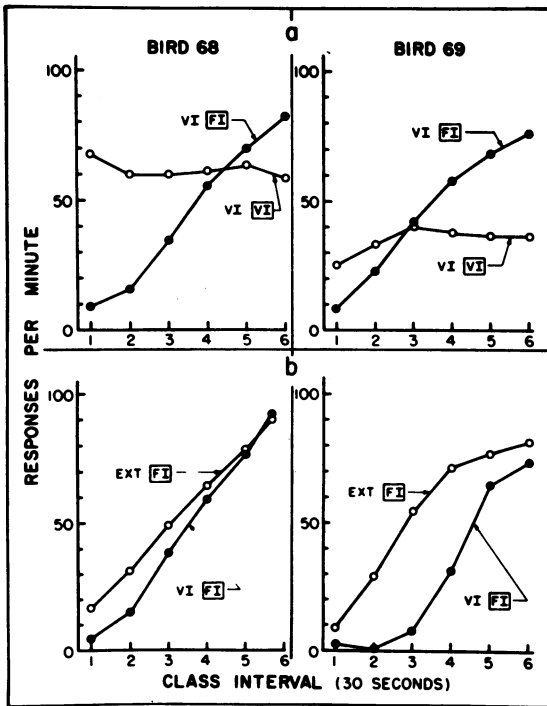


Fig. 1a. The rate of responding maintained by VI 3 (unfilled circles) and FI 3 (filled circles) in successive 30-second intervals of 3-minute presentations of a blue key. The schedules were alternated with 3 minutes of VI 3 in the presence of an orange key.

Fig. 1b. The rate of responding in successive 30-second intervals of FI 3. The schedule alternated with extinction (unfilled circles) and with VI 3 (filled circles).

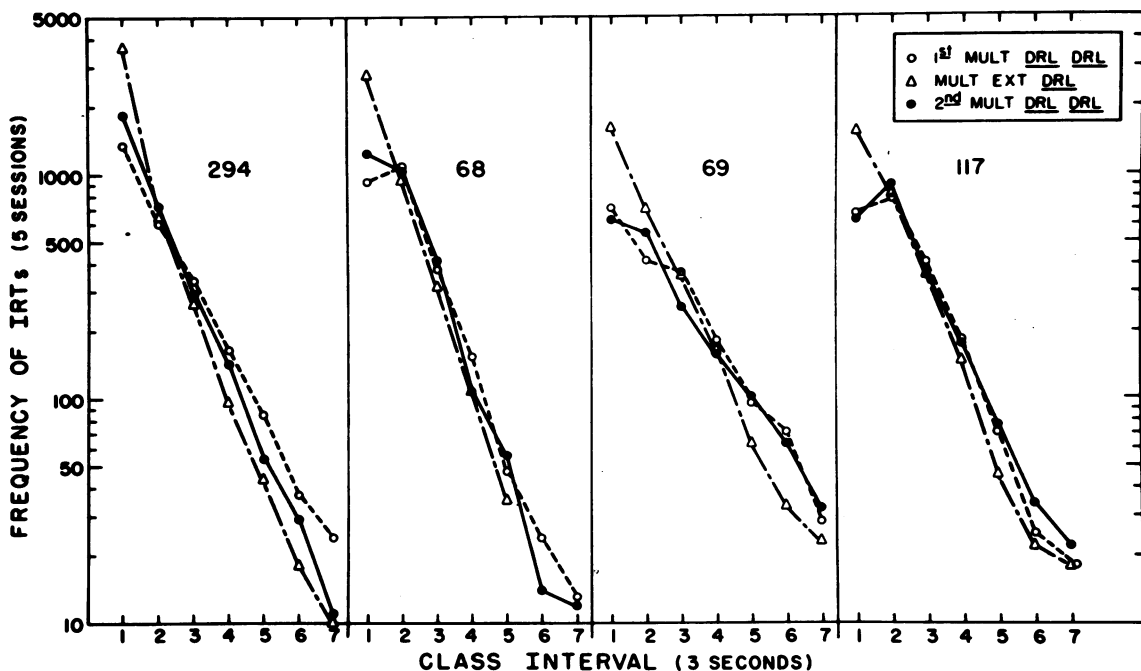


Fig. 2. Distributions of inter-response times on DRL 21 sec. in the presence of a blue key. For the circles, the schedule during alternated presentations of an orange key was DRL 21 sec.; for the triangles, it was extinction.

Except for responses in the first class interval, the functions in Fig. 2 are approximately linear. Since the ordinate is logarithmic, the number of IRT's of a given length is approximately a negative exponential function of the length of the IRT. This is the function that is generated when responding is random with respect to time (Anger, 1956). More than 100 hours of DRL 21 sec. in one component of a two-component multiple schedule produced a low rate of responding, but little additional control over the distribution of responses with respect to time.

The circles in Fig. 2 show the IRT distributions from the presentations of blue in the schedule mult DRL 21 sec. DRL 21 sec. The performances before and after the programming of extinction during orange are shown by the filled and unfilled circles, respectively. The triangles show that the change from DRL to extinction during orange increased the frequency of short IRT's (0 to 3 seconds, class interval 1) during blue, and hence the rate of responding during blue. This increase in response rate led to a decrease in the frequency of reinforcement during blue. The original performance was recovered after DRL was reinstated during orange.

The magnitude of the increase in responding is indicated in Fig. 3, which shows the change in the number of IRT's per opportunity in each class interval. The statistic IRT's per opportunity (IRT's/Op), whose advantages are discussed by Anger (1956), is defined as the number of IRT's of a given duration

divided by the number of IRT's of that duration or greater. It is thus a relative frequency of responses in a given interval of time after a preceding response, based on the number of opportunities the pigeon had to respond in that interval of time. In this sense, IRT's/Op is a measure of the probability that a re-

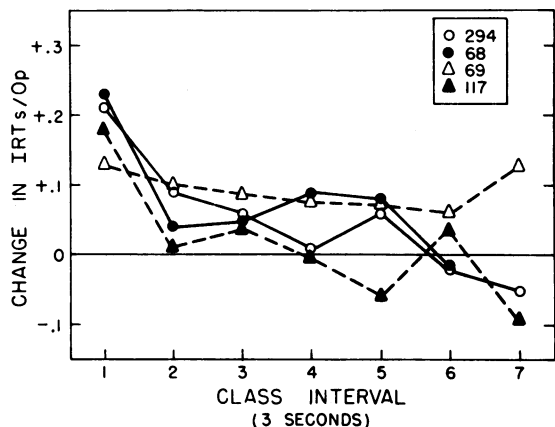


Fig. 3. The change in IRT's/Op during the presentation of blue (see text) produced when DRL reinforcement during orange was discontinued. A positive change indicates that the probability of a response was higher when DRL 21 sec. alternated with extinction than when it alternated with DRL 21 sec.

sponse will occur in a given interval of time after a preceding response. Figure 3 shows that when the schedule during orange was changed from DRL 21 sec. to extinction, the increase in IRT's/Op (response probability) during blue was greatest for the short IRT's.

#### DISCUSSION

When reinforcement was discontinued during the presentation of one of two alternated stimuli, the rate of responding maintained by FI or DRL reinforcement during the presentation of the other stimulus increased. This increase in the rate of responding, called behavioral contrast, has also been demonstrated in experiments with variable-interval, variable-ratio, and fixed-ratio reinforcement in multiple schedules (Reynolds, 1961 a, 1961 b) and with variable-interval reinforcement in combined multiple and concurrent schedules (Catania, 1961). These experiments have shown that a reduction, rather than a complete discontinuation, of reinforcement during one stimulus produces contrast during a different stimulus, and that changes that do not reduce the frequency of reinforcement during one stimulus do not produce contrast during the other.

Several interpretations of the way in which a decrease in reinforcement frequency produces contrast are called into question by the occurrence of contrast with FI and DRL schedules. The three interpretations of contrast that will be considered here appeal to differential reinforcement or to differential punishment of inter-response times (IRT's). It may be said in advance that none of the three adequately accounts for contrast.

(1) Ferster (1958) has suggested that the interruption of a VI schedule of reinforcement by stimulus-correlated periods of extinction indirectly results in differential reinforcement of short IRT's. The longer the pause after a response the greater the probability that the pause will be interrupted by the onset of the extinction stimulus. Therefore, the probability of a response after a long pause decreases. Relatively fewer responses after long pauses means relatively more reinforced responses after short pauses. This is differential reinforcement of short IRT's.

In DRL contrast, however, only responses following pauses of more than 21 seconds were reinforced, whereas the rate increase was largely the result of an increase in the frequency of responses following pauses of from 0 to 3 seconds.

(2) Since a long pause is more likely to be interrupted by the extinction stimulus than a short pause, it might be suggested that the onset of the extinction stimulus differentially punishes long pauses. Such an account is plausible because of Ferster's (1958) demonstration that an organism's rate of responding may be manipulated by differentially punishing IRT's with the onset of a stimulus correlated with extinction. The greater probability of punishment for long pauses

would be expected to produce a decrease in the frequency of long pauses, and therefore an increase in the rate of responding.

In the present FI contrast, however, the last pause (the last IRT) in the presence of the FI stimulus was probably not punished by the onset of the extinction stimulus, since this pause was always terminated by a reinforced response.

(3) Jenkins (1961), using a trial-by-trial procedure with pigeons, obtained a decrease in the response latency to one stimulus after introducing, on some of the trials, a second stimulus correlated with extinction. If his account of the decrease in latency were extended to a free-operant situation, it would be as follows. As discrimination progresses, the IRT's during the extinction stimulus become longer. Consequently, the IRT's during the stimulus correlated with reinforcement become relatively shorter, although they may remain of the same absolute duration. Since reinforcement then occurs for relatively short IRT's, the rate of responding increases in the stimulus correlated with reinforcement, as it does with ordinary differential reinforcement of short IRT's.

This account suffers from the same difficulty as the first account. It is difficult to explain an increase in the frequency of responses after pauses of from 0 to 3 seconds by appealing to the fact that pauses of 21 seconds or more in the DRL stimulus have become relatively shorter than those between responses in extinction in the presence of a different stimulus.

Although in every experiment surveyed here an increase in the rate of responding in the presence of one stimulus was produced by a decrease in the frequency of reinforcement in the other, it does not yet seem possible to derive all examples of contrast from known effects of reinforcement on distributions of inter-response times. It may prove more fruitful to analyze contrast in terms of changes in the relative frequency of responding brought about by changes in the relative frequency of reinforcement. (See Reynolds, 1961 b, 1961 c.)

#### SUMMARY

Both fixed-interval and DRL schedules of reinforcement maintained higher rates of responding when alternated with stimulus-correlated periods of extinction than when alternated with stimulus-correlated schedules of positive reinforcement. The increase in rate in FI was greatest early in the interval and least just before reinforcement. The increase in response probability (IRT's/Op) in the DRL was greatest for short IRT's.

The rate increases do not appear to depend on differential reinforcement or differential punishment of inter-response times.

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