# THE EFFECT OF CONTINGENCY UPON THE APPETITIVE CONDITIONING OF FREE-OPERANT BEHAVIOR

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The problem of maintaining independence between response rates and reinforcement probabilities when determining the effect of varying the response-reinforcement contingency upon free-operant behavior was solved by programming local reinforcement probabilities for response and no response on a second-by-second basis. Fifty-seven rats were trained to lever-press on schedules of water reinforcement involving different values of contingency. All rats were first trained on a high positive contingency and then shifted to less positive, zero, or negative contingencies. Under these conditions, rate of lever-pressing declined appropriately when the contingency between response and reinforcement decreased or was made negative. The decline in rate produced by a zero contingency cannot be attributed to extinction, since the probability of reinforcement given the occurrence of a response was the same as for the positive contingency from which the shift to zero was made. That is, there was no change in the opportunity for response-reinforcement contiguity. It was concluded that the technique of programming local reinforcement probabilities offers promise for more critical examinations of the effects of contingency upon free-operant behavior.
Key words: contingency, appetitive conditioning

Contingency is often defined as the difference between the probability of reinforcement given a response and the probability of reinforcement given the absence of that response. When such a contingency definition is applied to free-operant paradigms, the experimenter faces a serious problem of how to program in advance the probabilities of the response and no response categories in a manner that is independent of response rate (see Gibbon, Berryman, & Thompson, 1974, p. 595). This technical problem, which has rarely been discussed, has effectively precluded examination of this type of contingency concept or any others which are also based on short-term reinforcement probabilities in the free-operant paradigm. The popularity of contingency explanations of operant behavior may stem from the well known rate-depressing effects of the shift from variable-interval (VI) reinforcement to free reinforcement on a variable-time (VT) schedule. However, such declines in response rate could be attributed to increases in the frequency of responses which are *not* followed by reinforcement on a VT as opposed to a VI schedule (e.g., Zeiler, 1968, p. 411).

Experiments which have been directly designed to evaluate the effect of contingency have all used a discrete-trial procedure (e.g., Neffinger & Gibbon, 1975), or one with many discrete-trial properties (e.g., Kop, Kadden, & Schoenfeld, 1974). For some unknown reason all such studies have used shock as the reinforcing stimulus. Other experiments (such as Lattal, 1974; and Herrnstein & Hineline, 1966) were not designed to evaluate contingency effects and consequently are inadequate to do so. For example, in the Lattal study, the so-called free reinforcements are actualy dependent upon the earlier occurrence of earned reinforcements.

The research described below illustrates the use of a technique that substantially, but not entirely, solves the problem of experimentally specifying reinforcement probabilities in the free-operant case. In addition, this research used an appetitive reinforcer paradigm. The advantages of this technique are: first, that the concept of contingency can now be investigated in a more precise fashion for free-operant paradigms; second, the technique can provide a critical comparison between response-reinforcement contiguity as the sole determiner

of operant conditioning versus response-reinforcement contiguity as only one of several determinants of operant conditioning. For example, the lack of reinforcement for the absence of responding in the operant situation may play an important role in operant conditioning. Surprisingly enough, such a comparison has never been made, because, as noted above, the lack of responding found on a VT schedule may be attributed just as readily to extinction as to lack of contingency.

The technique extends the discrete-trial paradigm to the free-operant paradigm by dividing the entire operant session into very brief unsignaled time periods each of which can be treated as a trial by the experimenter. Since these trials are unsignaled and there is no intertrial interval, the procedure is free-operant for the organism. In the present experiments the time base for a "trial" was one second. One momentary probability of water reinforcement could be assigned for each second in which at least one response occurred, while a second independent momentary probability could be assigned for each second in which no response occurred. In this way, it is possible to approximate the probability values for reinforcement given a response and for reinforcement given the absence of a response. In both experiments described below, rats were first trained on a high positive contingency and then shifted to a contingency of lower value or a negative contingency. The first experiment examined a shift from high positive to zero contingency, using an ABAB design. The second experiment examined shifts from high positive to lower positive contingencies, zero contingencies, or to a high negative contingency.

## EXPERIMENT I

### METHOD

#### Subjects

Ten male albino rats with no previous experimental history served and were maintained on a 23-hr water deprivation schedule throughout the experiment.

#### Apparatus

The experimental spaces consisted of ten Lehigh Valley Electronics (LVE) operant conditioning chambers, each equipped with one LVE retractable lever to the right of the LVE water dipper and a 28-V dc light with frosted-glass lens mounted just above the lever. Events in these chambers were scheduled by paper tape driven electromechanical equipment located in the next room. Responses were recorded on mechanical counters and monitored continuously on a 20 channel Esterline-Angus event recorder.

#### Procedure

After one week of handling and deprivation, the rats were given a single 1-hr session of magazine training in which they received 60, .03cc water reinforcements on a variable-time (VT) 60-sec schedule, with the lever retracted from the chamber. After this single session of magazine training all rats were always exposed to one of the values of our particular procedure for programming contingency.

The programming equipment divided the session into a repeating 1-sec cycle. Reinforcements were delivered only at the end of a cycle and these reinforcements were conditional upon the occurrence or nonoccurrence of at least one response during that cycle and upon the predetermined holes in the paper tape. One channel of the paper tape was reserved for reinforcements when a rat did respond, and one for reinforcement when the rat did not respond in a given cycle. At the end of each 1-sec cycle the equipment detected whether the rat had, or had not, responded and then sampled the appropriate channel of the tape. If there was a hole in that channel, a reinforcement was delivered. Thus, when reinforcements occurred, they always came a constant fraction of a sec (programming time) after the end of the 1-sec cycle. When responses are reinforced some of the time, but no reinforcements occur following the absence of a response during a 1-sec cycle, this schedule is identical to what has been called a random-interval schedule with $T = 1$ sec (e.g., Millenson, 1963). Since rats are capable of responding more than once per sec, more than one response may have occurred in any given sec. Only one of the responses in any sec could actually produce reinforcement just as only the last response on an interval schedule has any influence upon reinforcement. The applicability of this technique to the study of contingency hinges upon these arbitrary as-

sumptions about the temporal definition of a response and a nonresponse.

The actual sequence of experimental conditions is shown in Table 1. The schedule for contingency will be labeled here as two reinforcement probabilities, the first for responding, the second for no responding. All ten rats received four sessions on the 1.0-0 schedule of reinforcement. The first two sessions were 60 min long, the second two sessions 50 min long. Thereafter they were shifted to a .2-0 schedule of reinforcement for six daily sessions of 40-min duration. Finally they were placed on a .05-0 schedule of reinforcement for 14 daily, 1-hr sessions.

Table 1
Summary of Experimental Conditions in Experiment I

| Condition | Number of Sessions | $P_{RFT/R}$ | $P_{RFT/\bar{R}}$ | Contingency |
|-----------|--------------------|-------------|--------------------|-------------|
| a | 4 | 1.0 | 0 | very high positive |
| b | 6 | .2 | 0 | high positive |
| c | 14 | .05 | 0 | moderately high positive |
| d | 18 | .05 | .05 | zero |
| e | 17 | .05 | 0 | moderately high positive |
| f | 18 | .05 | .05 | zero |

After this rather extensive history of reinforcement with a moderately high positive contingency between lever pressing and water delivery, all ten rats were shifted to a zero contingency produced by a .05-.05 schedule of reinforcement. Under these conditions the consequences of responding remained the same; only the consequences of not responding changed, from a probability of 0 to .05. Thus, a zero contingency was defined as a condition with equal likelihood of reinforcement for either a response or no response in any given sec.

The rats were maintained on the zero contingency of .05-.05 for 18 daily 1-hr sessions administered on a 5-day-a-week basis. At the end of this zero-contingency phase, these ten rats were returned to the moderately high positive contingency (.05-0) for 17 additional daily sessions and then shifted once again to the zero contingency (.05-.05) condition for 18 more sessions. In short, Experiment I involved an ABAB design.

## RESULTS

The mean response rate for all ten rats for each session throughout Experiment I is shown in the uppermost graph of Figure 1. The response rates per session for two individual animals, R-8 and R-10, are shown in the middle and lower graphs of Figure 1. R-8 and R-10 were selected for depiction because they represent the two extreme cases. The mean response rate for the last 5 trials (trials 10-14) of the .05-0 contingency was taken as the baseline rate. Performance on the zero contingency was assessed in terms of the percentage of the baseline rate. By this measure R-8 shows the greatest depression of response rate while R-10 shows the least.

As can be seen from the graph for R-10, all animals showed a substantial decline in responding upon introduction of the zero contingency. It is also the case that all rats showed a substantial decline the second time they were shifted to the zero contingency. In fact the decline was greater for the second than for the the first shift. The mean percent baseline rate for the first shift was 22.7%, range 32.8% to 9.5%; while the average for the second shift was 12.1%, range 21.5% to 2.0%. These percent baseline rates were based in each case upon the mean of the last five sessions of the positive contingency and the mean for all sessions in each zero contingency. The difference in percent baseline rate between the first and second shift was significant (Wilcoxian, paired scores, signed ranks test, T = 6, N = 10, p < .05). Eight of the ten rats showed a greater rate-depressing effect the second time they were exposed to the zero contingency as compared with the first time.

## EXPERIMENT II

The purpose of Experiment II was to examine the effects of a negative contingency and an intermediate positive contingency. In order to compare performance systematically on a wide range of contingencies, it was necessary to first develop a high rate of responding. For this reason all rats were always trained first on a high positive contingency and then shifted to a lower contingency as in Experiment I. Since Experiment I showed that exposure to an initial contingency shift changed performance on a second contingency shift
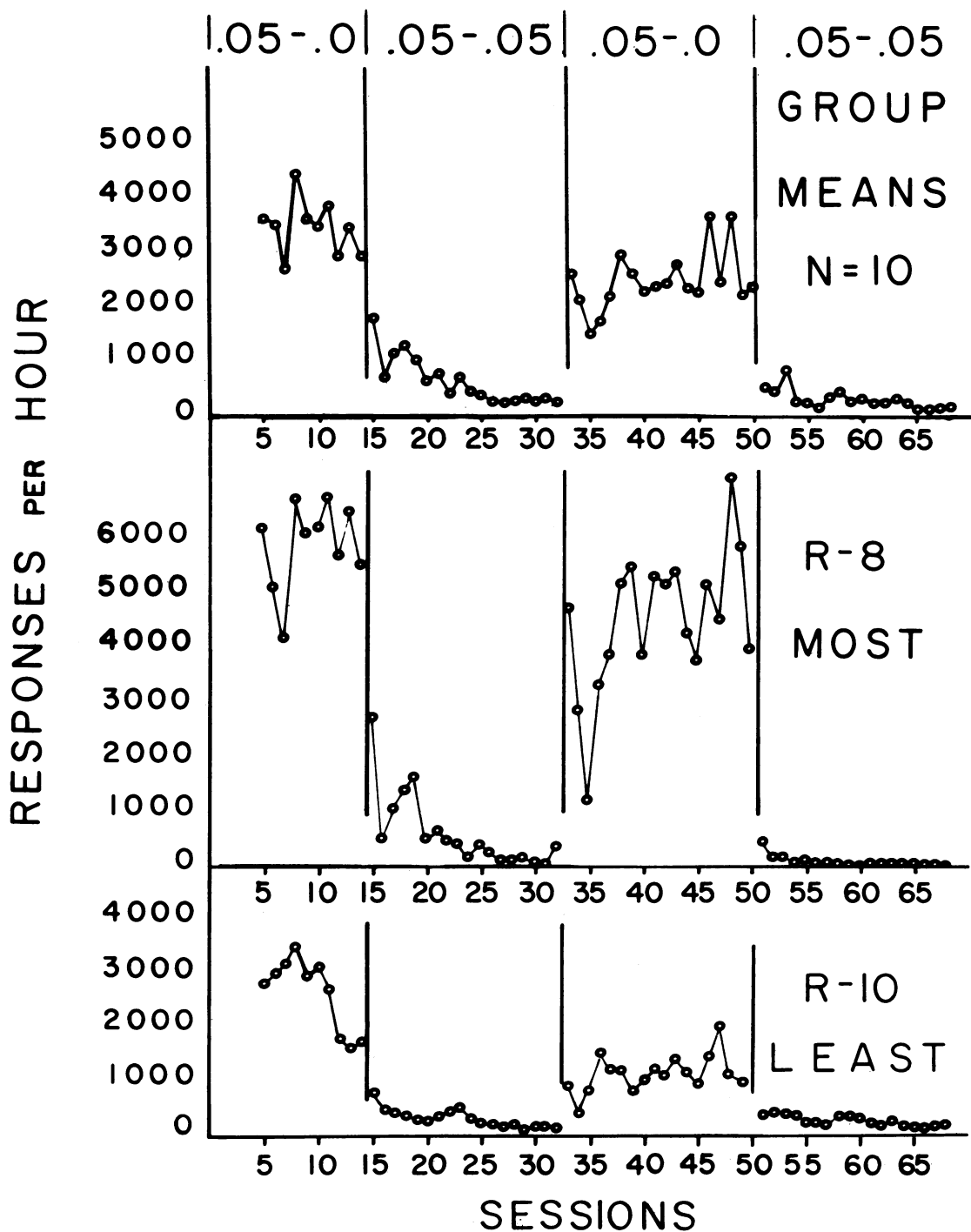
Fig. 1. Responses per hour for sessions of Experiment I. The top graph represents the mean response rate for all ten rats, the two lower graphs depict the two subjects which showed the most and the least effect of the shifted contingency.

identical to the first, it was necessary to make the comparisons in Experiment II between, rather than within, rats. A shift to zero contingency was included in each comparison.

## METHOD

### Subjects

47 male, experimentally naive albino rats served and were maintained as in Experiment I.

### Apparatus

The apparatus was identical to that used in Experiment I.

### Procedure

All rats were pretrained as before, including the magazine training for water reinforcement in their first experimental session. The sequence of experimental conditions following magazine training is shown in Table 2. First they were placed on a 1.0-0 schedule of reinforcement administered in the same manner as in Experiment 1 for one session. Rats R-21 through R-29 constituted a zero contingency group which was compared to the negative contingency of Rats R-31 through R-38. These 17 rats were trained for 15 hourly sessions on a .05-0 schedule of reinforcement and then the zero group was shifted to a .05-.05 schedule and the negative group to a .0-.05 schedule for 22 hourly sessions.

The remaining 30 rats were divided into three equal groups to assess an intermediate contingency effect. These animals were trained

and tested during 30 min sessions on higher reinforcement density schedules, because pilot work suggested that this might increase the discriminability of the intermediate contingency. They were trained initially on a .12-0 schedule for 25 half-hr sessions and then were shifted to either zero (.12-.12), intermediate (.12-.08) or were returned to the same positive (.12-0) contingency of reinforcement for an additional 25 sessions. Daily sessions were conducted on a five day per week schedule.

## RESULTS

The left side of Figure 2 depicts the zero versus negative contingency comparison, while the right side depicts the comparisons for evaluating intermediate effects. As in Experiment I, the top graph (on each side) shows group means for each session, while the graphs below are for the rats with the most and least depressed performance following the particular contingency shift. The extreme cases were selected by the same criteria as before. There was no overlap in percent baseline between the eight rats of the negative group and the nine rats of the zero group (the mean for the zero group = 20.6%; the mean for the negative group = 2.9%; Mann Whitney U score = 0, p < .001). As anticipated, the negative contingency was much more effective than the zero contingency in suppressing behavior.

The intermediate contingency comparisons were less striking but were still in the expected direction. All 10 of the rats in the positive group, which was maintained on the same

Table 2
Summary of Experimental Conditions in Experiment II

| Rats | Condition | Number of Sessions | $P_{RFT/R}$ | $P_{RFT/\bar{R}}$ | Contingency |
|------|-----------|--------------------|-------------|-------------------|-------------|
| R-21 through R-29 | a | 1 | 1.0 | 0 | very high positive |
| | b | 15 | .05 | 0 | moderately high positive |
| | c | 22 | .05 | .05 | zero |
| R-31 through R-38 | a | 1 | 1.0 | 0 | very high positive |
| | b | 15 | .05 | 0 | moderately high positive |
| | c | 22 | 0 | .05 | strongly negative |
| R-51 to R-60 | a | 1 | 1.0 | 0 | very high positive |
| | b | 25 | .12 | 0 | high positive |
| | c | 25 | .12 | .12 | zero |
| R-31 to R-40 | a | 1 | 1.0 | 0 | very high positive |
| | b | 25 | .12 | 0 | high positive |
| | c | 25 | .12 | 0 | high positive |
| R-41 to R-50 | a | 1 | 1.0 | 0 | very high positive |
| | b | 25 | .12 | 0 | high positive |
| | c | 25 | .12 | .08 | intermediate positive |
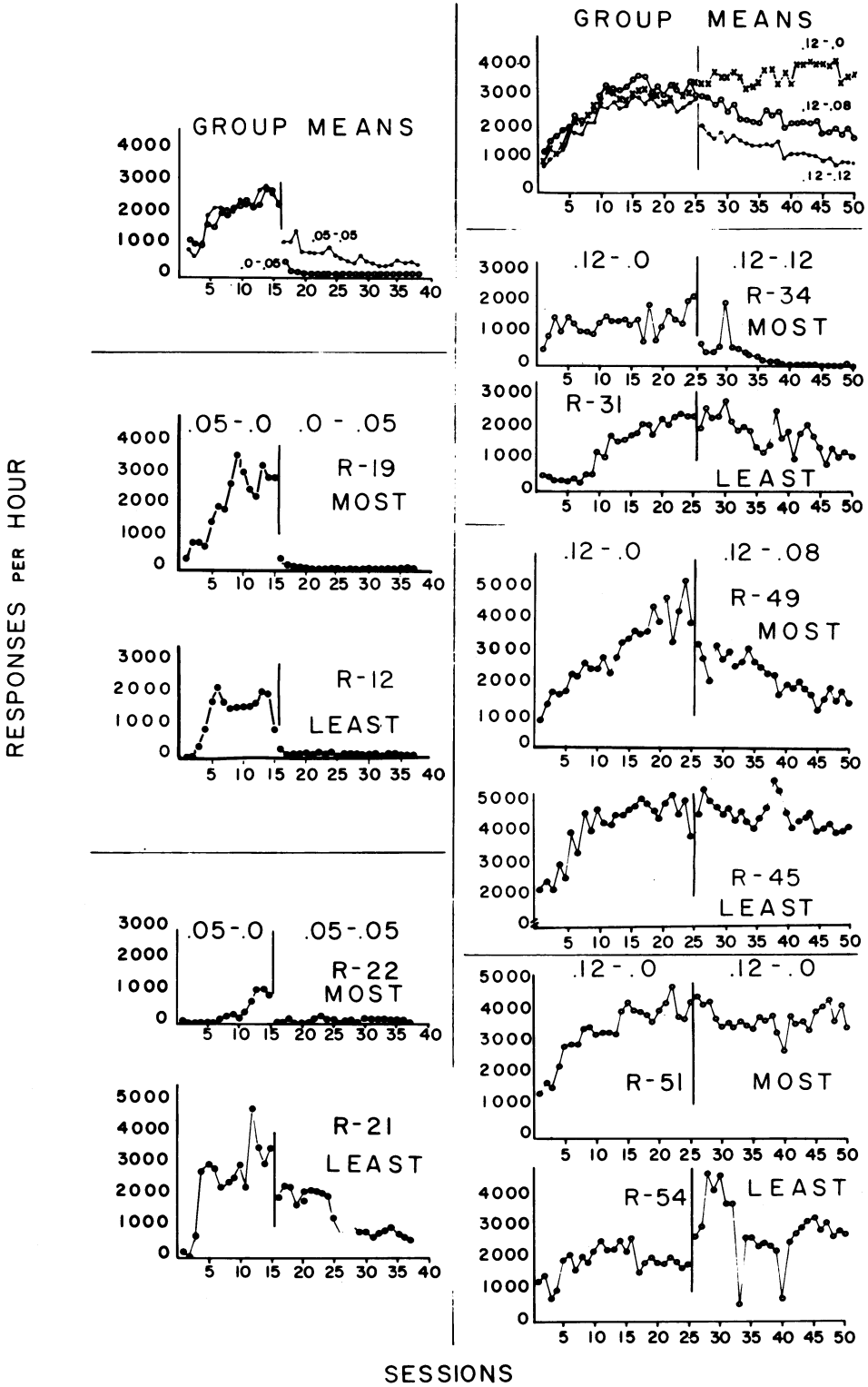
Fig. 2. Responses per hour for sessions of Experiment II. The left side represents a comparison between a shift to zero versus a shift to a negative contingency. The right side represents a comparison of an intermediate, positive contingency to a high positive and a zero contingency.

schedule (.12-0) throughout, actually increased their performance after the other groups were shifted; while both the degraded contingencies produced lower responding in 19 of 20 rats. Based on percent baseline rates, there was no overlap between the zero group (mean = 45.0%) and the positive group (mean = 121.9%; $n_1$, $n_2$ = 10, Mann-Whitney U = 0, p < .001); and there was only one instance of overlap between the intermediate (mean = 68.4%) and the positive group (U = 1, p < .001). But there was considerable overlap between the zero and intermediate groups (U = 21, p < .05) as can be seen by comparing the least depressed rat of the zero group, R-31, with the most depressed rat of the intermediate group, R-49. Although the intermediate contingency, generally speaking produced intermediate rate depressing effects, individual differences in reactivity to these lowered contingencies were considerable.

## DISCUSSION

The major purpose of the present research was to examine a new technique for programming reinforcement probabilities following the occurrence of a response and the absence of that response in an appetitive free-operant paradigm in such a way that these probabilities would always be independent of the animal's overall rates of responding. Only when such independence is achieved can the components of a contingency (defined as the difference between the probability of reinforcement given a response and the probability of reinforcement given the absence of that response) be programmed in advance. Therefore only with such a technique can one begin to examine empirically the many predictions generated by contingency, as defined above, on free-operant behavior.

The present experiments demonstrate a relationship between behavioral change and changes in contingency. However, only widely separated contingency values were compared, and in this sense the demonstrated relationship is very crude. These findings then, do not incisively examine the effects of contingency, since the absolute difference between reinforcement given a response and reinforcement given no response is only one of a potentially large class of mathematical formulae specifying the relationship between the entries in the four cells of a contingency matrix (see Gibbon et al., p. 595).

What these results do clearly show is that the rate-depressing effects of response-independent reinforcement are not the result of simple extinction of responses previously strengthened by response-reinforcement contiguity. When rats were shifted to a zero contingency, the technique used here maintained the same opportunity for response-reinforcement contiguity as existed on the high positive contingency which established the behavior. One must look elsewhere for an explanation of the rate-depressing effects of response-independent reinforcement.

As noted before, the assessment of different contingency definitions (e.g., reinforcement probability difference versus statistical correlation between response and reinforcement) has not been possible in free-operant paradigms because methods were lacking for specifying the reinforcement probabilities following response and the absence of the response independently of overall response rate. The present technique appears to provide one approach to accomplishing the large scale effort required to make an assessment of contingency. However, one must accept certain assumptions upon which the technique is based. Most important, is it appropriate to define a response as an act in time (such as was done by Baum and Rachlin, 1969) rather than as a discrete act? With the particular values of the technique used here a response was defined as at least one lever press in any second, while a non-response was defined as the absence of any responses in a second. The question about the adequacy of this assumption arises because we have no idea whether or not the organism is best described on the basis of similar principles of response and no-response quantification. If the animal fails to press the lever for five seconds, should that be treated by the experimenter as five instances of the absence of a response (as was done here) or as one, or how should it be treated? Perhaps further research with different time cycles than once per second will help clarify this issue.

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