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# RESPONSE-REINFORCER DEPENDENCE AND INDEPENDENCE IN MULTIPLE AND MIXED SCHEDULES

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Albino rats were conditioned to lever press during two-component multiple and mixed schedules in which response-dependent and response-independent reinforcers occurred in the different components. Relative response rates in the components associated with response-dependent reinforcers were higher (a) when different visual and auditory stimuli were associated with the two components and (b) when mixed schedule components were long in duration. These results illustrate the contribution of the response-reinforcer relation to stimulus control and schedule control of behavior. They also suggest that under some conditions, reinforcers need not be consistently associated with a particular response to ensure that the response is maintained at a relatively high rate.

Multiple schedules may be considered as mixed schedules in which distinct exteroceptive stimuli are associated with the different components (Ferster and Skinner, 1957). When different contingencies of reinforcement are arranged in the components of multiple schedules, behaviors appropriate to the different contingencies can be obtained. In the absence of different exteroceptive stimuli in the components, *i.e.*, during analogous mixed schedules, reinforcement contingencies in the components can control differential responding. For example, control during mixed schedules has been frequently observed when one component of the mixed schedule is extinction and the other is some schedule of positive reinforcement (Ferster and Skinner, 1957, chapter 11; Weissman, 1960; Sadowsky, 1969). Sadowsky (1969) concluded that, during multiple schedules, differential responding in the components may be attributed jointly to the control of the exteroceptive stimuli in effect and to control exerted by the different reinforcement contingencies in the different components, independently of the exteroceptive stimuli.

Experiments comparing the control of responding by positive reinforcers dependent upon a response to those delivered independently of responding have frequently used multiple schedules in which these two different response-reinforcer relations were associated with different exteroceptive stimuli (*e.g.*, Appel and Hiss, 1962; Lattal and Maxey, 1971). Under these conditions, response rates in the component associated with response-dependent reinforcers were higher than rates in the component associated with response-independent reinforcers. A reversal of the exteroceptive stimuli resulted in response rate changes in the two components consistent with the appropriate response-reinforcer relation in each component (Lattal and Maxey, 1971). Appel and Hiss (1962) cited the different response rates in the two components as evidence of the discriminative properties of the response-dependent and response-independent positive reinforcers. The present experiment examined (a) the extent to which such findings result from an interaction of the underlying mixed schedule of reinforcement and the exteroceptive stimuli and (b) conditions under which different response-reinforcer relations can control different response rates in the absence of distinct exteroceptive stimuli.

## METHOD

### *Subjects*

Five experimentally naive male albino rats were maintained at 80% (±3%) of free-feeding weight. Each was approximately 120 days old at the beginning of the experiment.

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*Apparatus*

A Lehigh Valley Electronics (LVE) model 1417 rat chamber was equipped with a Davis model 104 pellet dispenser that delivered 45-mg standard Noyes food pellets as reinforcers. The operandum was a LVE model 1352 rat lever operated by a force of approximately 0.15 N. Bright and dim levels of houselight illumination were generated by the 30-V ac and 10-V ac outputs of a LVE model 1429 ac transformer panel. A click generator (BRS model CG 201) was used to provide an auditory click stimulus (approximately 15 clicks per second). Solid state control and recording equipment were located in an adjacent room.

*Procedure*

After shaping the lever-press response, each subsequent response produced a food pellet during two successive sessions in which a total of 150 pellets was delivered. Responding during multiple variable-interval 1-min variable-time 1-min (*mult* VI 1-min VT 1-min) and mixed variable-interval 1-min variable-time 1-min (*mix* VI 1-min VT 1-min) were investigated with Rats 47 and 54. During the VI 1-min schedule, reinforcer delivery was response-dependent and during the VT 1-min schedule, reinforcers were delivered independently of lever-press responding. The temporal distribution of reinforcers in both VI 1-min and VT 1-min was arranged by a single, continuously running film programmer. The range of intervals between successive reinforcers was approximately 10 sec to 2.5 min. Components of 5-min duration were randomly arranged such that at the end of any 5-min component there was a 0.50 probability of either VI or VT occurring next. Sixty minute sessions were conducted five days a week. The bright houselight was illuminated during VI 1-min, and the dim houselight was illuminated and the clicker was on during VT 1-min when the multiple schedule was in effect. The dim houselight and clicker were in effect in both VI 1-min and VT 1-min components during the mixed schedule. The terms multiple and mixed are used here only to describe the presence or absence of different visual and auditory stimuli in the two components. There were still, of course, potential discriminative stimuli in the different components, *i.e.*, the presence or absence of a response-reinforcer dependency. The sequence of schedules for Rats 47 and 54 is summarized in Table 1.

Table 1

Sequence of multiple and mixed schedules for Rats 47 and 54.

| Schedule | Number of Sessions | |
|---|---|---|
| | *Rat 47* | *Rat 54* |
| *mult* VI 1-min VT 1-min | 15 | 15 |
| *mix* VI 1-min VT 1-min | 12 | 12 |
| *mult* VI 1-min VT 1-min | 15 | 25 |
| *mix* VI 1-min VT 1-min | 45 | 45 |
| *mult* VI 1-min VT 1-min | 30 | 30 |

The effect of component duration on responding during mixed VI 1-min VT 1-min was investigated with Rats 45, 46, and 53. The other parameters of the schedule were identical to the mixed schedule used with Rats 47 and 54 already described. Table 2 provides the sequence of component durations for these subjects. VI and VT components were randomly distributed throughout the session, as described above, during the 5- and 10-min components. During the 30-min components, one VI and one VT component was arranged per 60-min session. VI and VT occurred first an equal number of times during such sessions. When VI and VT were in effect for entire sessions (60-min components), they were alternated for the first two sessions, randomly arranged for the third session, but the fourth session was always the alternate of the third. Thirty two to thirty six successive sessions were arranged in this way so that every set of two daily sessions consisted of a VI and a VT.

## RESULTS

Figure 1 presents response rates of Rats 47 and 54 during the multiple and mixed schedules. The distribution of total responses be-

Table 2

Sequences of mixed VI 1-min VT 1-min schedule component durations for Rats 45, 46, and 53.

| Component Duration | Number of Sessions | | |
|---|---|---|---|
| | *Rat 45* | *Rat 46* | *Rat 53* |
| 5 min | 30 | 30 | 30 |
| 30 min | 32 | 22 | 30 |
| 60 min | 34 | 32 | 36 |
| 10 min | 30 | 30 | 30 |

tween VI and VT components is expressed as relative VI response rates (response rate in VI/response rate in VI + response rate in VT). Absolute response rates in VI were higher than those in VT during Sessions 1 to 15 (multiple schedule). Responding developed in VT and was maintained during the sessions even though the animals had not been exposed to the visual and auditory stimuli associated with this component during shaping of the lever-press response. Relative rates in VI were consistently higher during the multiple schedules than during the mixed schedules. The change from multiple to mixed generally resulted in increases in VT response rates, even though the stimuli previously associated with VT 1-min were in effect in both components. Rates in VI 1-min did not change in any systematic manner during the mixed schedule. Reinstatement of the multiple schedule resulted in separations in absolute rates in the two components.

Figure 2 compares relative VI response rates, as defined above, during the different mixed schedule component durations investigated with Rats 45, 46, and 53. In computing this measure for the 60-min components, successive pairs of sessions, consisting of one VI and one VT session, were used. At all component durations, relative VI rates were generally above 0.50, indicating somewhat higher response rates during the component in which reinforcers were response-dependent. Increasing the component durations increased relative VI response rates. These changes in relative VI rates reflected changes in absolute response

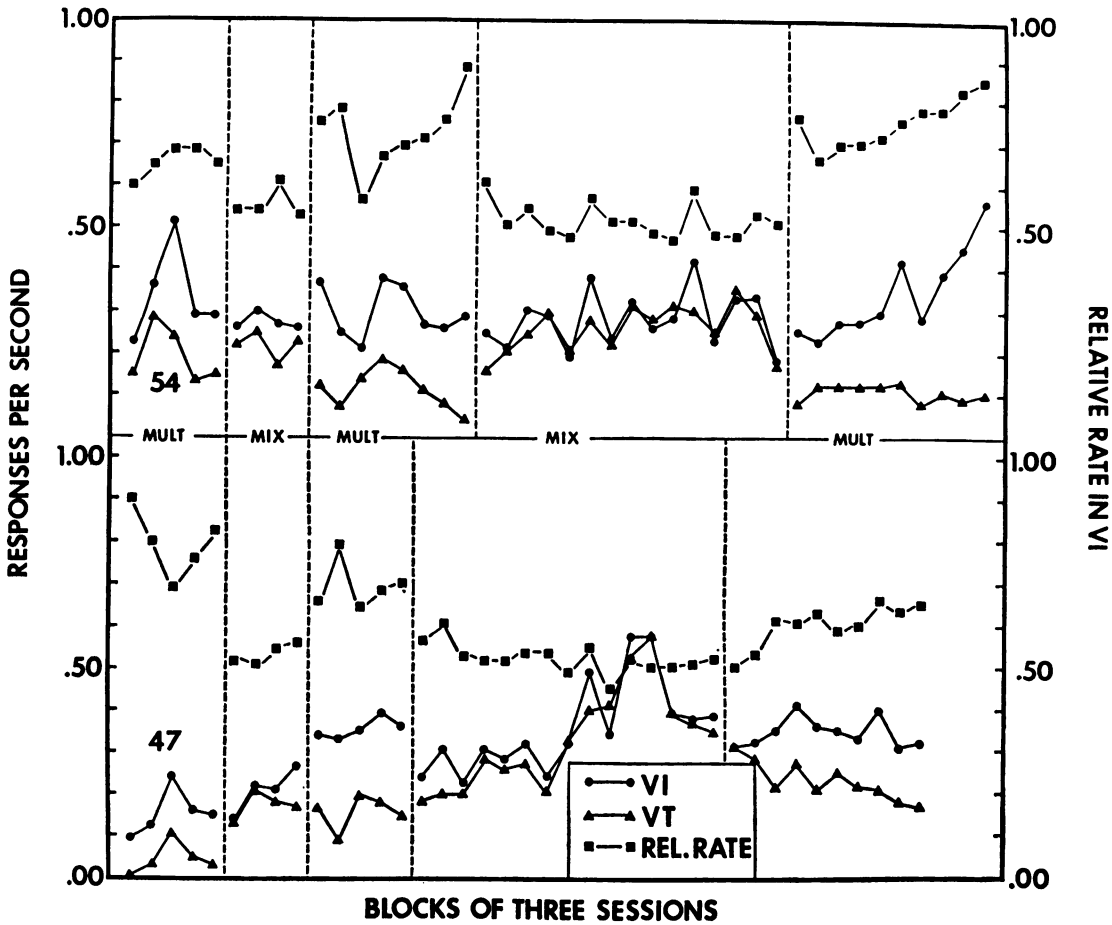


Fig. 1. Absolute VI and VT and relative VI response rates of Rats 47 (lower half of figure) and 54 (top half of figure) during successive exposures to *mult* VI 1-min VT 1-min and *mix* VI 1-min VT 1-min. The type of schedule (multiple or mixed) in effect is indicated on the horizontal mid-line separating the data of the two rats. The vertical lines delineate successive experimental conditions (multiple or mixed schedules).

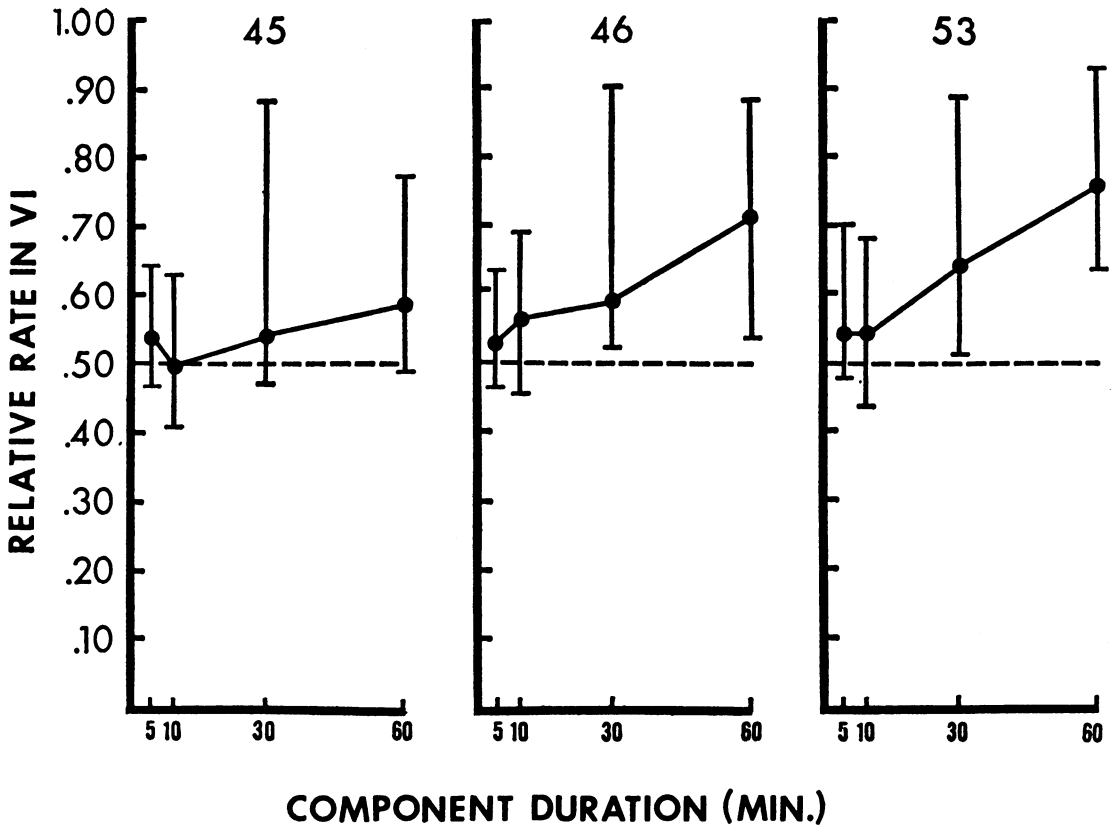


Fig. 2. Median values and ranges of relative VI response rates for Rats 45, 46, and 53 during the different *mix* VI 1-min VT 1-min component durations. All sessions at a given component duration were included in deriving the data in this figure.

rates in both VI and VT. Absolute response rates during the different component durations were variable (Table 3). Response rates in VI generally increased as the component durations were increased from 5 to 30 to 60 min, but VT response rates varied with the different animals. The decrease to 10-min components also had different effects on absolute rates, but decreases in relative VI rates from the 60-min component duration condition were observed with each subject. The data summarized in both Figure 2 and Table 3 represent all sessions at the given component durations.

The patterns of responding during individual sessions in VI and VT (Figure 3) resembled those previously reported (Zeiler, 1968). Responding was maintained during both VI and VT at all component durations. The longer the component duration the more closely the response rates conformed to the appropriate response-reinforcer relation. For example, beginning at point *a* in Figure 3, three 5-min VI components occurred in succession, followed by three VT components. Response rates were progressively higher in successive VI components and progressively lower during successive VT components. Similarly, during 60-min components, VI response rates were higher in the second 30-min of the session (beginning at points *b*) and VT rates were lower in the second 30-min of the session (beginning at points *c*).

During the 30-min components, the sequence in which VI and VT occurred affected the absolute response rates in these two components and, for Rats 46 and 53, the distribution of responses between the two components. Absolute response rates in both VI and VT were generally higher if VI occurred before VT than when VT occurred first in a session. With Rats 46 and 53, relative VI rates were generally higher when VT preceded VI in the session.

Table 3

Medians and ranges of absolute response rates in VI 1-min and VT 1-min components during each component duration for Rats 45, 46, and 53. The data were derived from all sessions at a given component duration.

| Component Duration (Min) | Responses per Second | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rat 45 | | | | Rat 46 | | | | Rat 53 | |
| | VI | | VT | | VI | | VT | | VI | VI |
| | MDN | Range | MDN | Range | MDN | Range | MDN | Range | MDN Range | MDN Range |
| 5 | 0.35 | 0.14-1.15 | 0.33 | 0.12-1.16 | 0.23 | 0.11-0.30 | 0.19 | 0.07-0.32 | 0.26 0.07-0.44 | 0.19 0.03-0.39 |
| 10 | 0.54 | 0.29-1.20 | 0.51 | 0.16-1.10 | 0.44 | 0.19-0.64 | 0.33 | 0.16-0.58 | 0.70 0.42-1.06 | 0.51 0.29-1.02 |
| 30 | 0.81 | 0.35-1.31 | 0.59 | 0.14-1.40 | 0.26 | 0.18-0.37 | 0.16 | 0.03-0.30 | 0.50 0.24-0.97 | 0.28 0.03-0.80 |
| 60 | 0.86 | 0.54-1.17 | 0.54 | 0.35-0.86 | 0.41 | 0.26-0.54 | 0.13 | 0.06-0.32 | 0.78 0.50-1.03 | 0.26 0.06-0.53 |

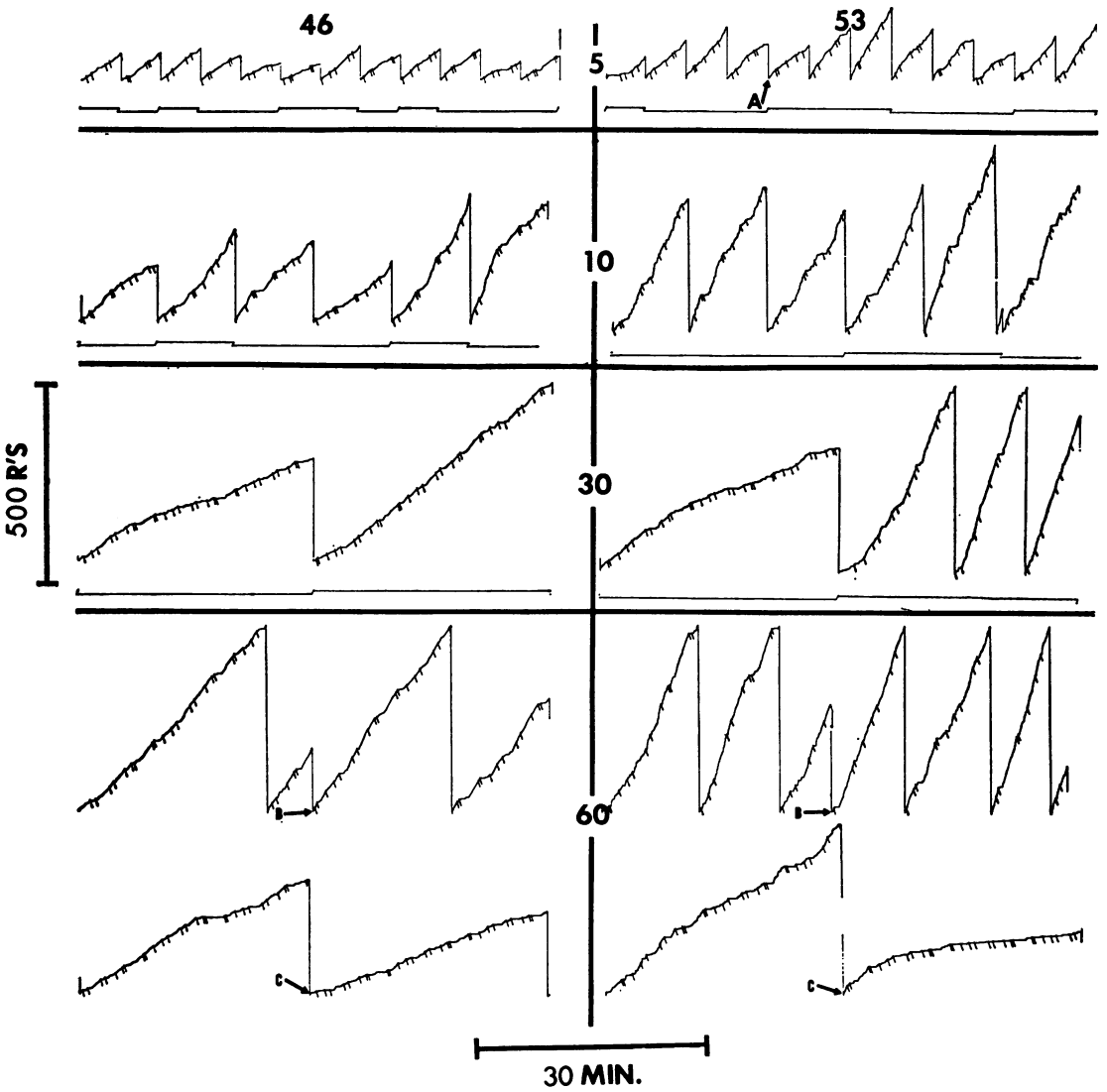


Fig. 3. Sample cumulative records of the performance of Rats 46 and 53 during the different *mix* VI 1-min VT 1-min component durations indicated at the center of each panel. In the 60-min component duration panels, the upper records are VI and the lower records are VT. Reinforcers are indicated as deflections of the response pen. The event pen is up during VI and down during VT. The response pen reset at the end of each component or, during the 60-min condition, at the end of the first 30-min of each session. See text for a description of points *a*, *b*, and *c*.

## DISCUSSION

In evaluating these data, a distinction between schedule control and stimulus control of behavior should first be made. In the former, the contingencies of reinforcement (*e.g.*, different response-reinforcer dependencies) can exert differential control over behavior independently of the exteroceptive stimuli. Stimulus control implies an interaction between the contingencies of reinforcement and the exteroceptive stimuli. Experiments employing multiple schedules in which the different components were associated with the delivery of response-dependent or response-independent reinforcers (*e.g.*, Appel and Hiss, 1962; Lattal and Maxey, 1971) showed that the combination of the different exteroceptive stimuli and the different response-reinforcer relations controlled rates of responding. The results obtained with Rats 47 and 54 demonstrate the importance of these exteroceptive stimuli in the control of responding in the

present experiments. As a result of changing to a mixed schedule, response rates in the variable-time component increased and, after differing numbers of sessions, were indistinguishable from response rates in the variable-interval component. If the response-reinforcer relations were serving discriminative functions in these experiments, consistent differences in responding in the two components would be expected to continue, or to develop, even though the exteroceptive stimuli in the components were the same. Thus, different response-reinforcer relations can contribute to the stimulus control of behavior but do not consistently exert schedule control over behavior in mixed schedules.

The data obtained from Rats 45, 46, and 53 also bear on this latter observation. Relatively longer component durations in the mixed schedules were associated with greater control of relative response rates by the appropriate response-reinforcer relation. This indicates that different response-reinforcer relations can, under certain conditions, exert differential control over behavior in the absence of distinct exteroceptive stimuli. However, it is reasonable to expect that any reinforcement contingency will exert increased control over behavior as it is in effect for longer temporal intervals. This increased control may arise in part from discriminative properties of the response-reinforcer relation in effect, but other variables must be considered of at least equal importance in interpreting such behavior. For example, the changes in relative responding in the components may be due to the direct action of the response-reinforcer relations upon lever pressing, rather than to any discriminative functions of such relations. For these reasons it seems inappropriate to use multiple or mixed schedules to evaluate the discriminative properties of response-reinforcer relations, as Appel and Hiss (1962) attempted to do. A more appropriate evaluation of such discriminative properties would be one in which the measure is not confounded with the schedule control of behavior, *i.e.*, some measure other than rate of responding. Such independent evidence might be obtained by the use of a matching-to-sample paradigm in which different response-reinforcer relations on one key are discriminative stimuli for responding on other, different choice keys.

Previous experiments have reported that continued exposure to schedules delivering response-independent reinforcers either in isolation or as components of multiple schedules resulted in progressive decreases in response rates across sessions (Appel and Hiss, 1962; Lattal, 1972; Lattal and Maxey, 1971; Zeiler, 1968). This effect did not occur in the present experiment. Rather, response rates during schedules delivering response-independent reinforcers were controlled by the presence or absence of distinct exteroceptive stimuli or by the duration of each component. By using a mixed schedule in which randomly arranged, relatively brief components associated with response-dependent or response-independent reinforcers occurred equally frequently, it was possible to maintain response rates in the absence of a response-reinforcer dependency at approximately the same rate as behavior maintained by response-dependent reinforcers. Thus, response rates need not be necessarily reduced when the response-reinforcer dependency is eliminated. This finding seems especially relevant for applied behavior analysis, where it is desirable to maintain certain behaviors with positive reinforcers, but it may not be always possible to arrange consistently for the delivery of all reinforcers to be response-dependent.

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