

COMBINATIONS OF RESPONSE-REINFORCER DEPENDENCE AND INDEPENDENCE¹

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The contribution of the response-reinforcer dependency to the control of behavior was investigated. Pigeons were trained to key peck under a variable-interval schedule of reinforcement. With the total number and temporal distribution of reinforcer deliveries in experimental sessions constant, the effects of varying the percentage of response-independent reinforcement were examined. At different times, 100%, 66%, 33%, 10%, or 0% of the scheduled reinforcers were delivered dependent upon key pecking and the remainder were delivered independently of responding. Response rates were related to the percentage of response-dependent reinforcement with lower response rates associated with smaller percentages of response-dependent reinforcement. The results suggest that the response-reinforcer relation exerts control over behavior in a manner similar to that exerted by other parameters of reinforcement.

A close and consistent temporal proximity between a response and the delivery of a reinforcer is a defining characteristic of the process of reinforcement. Such a response-reinforcer relation is imposed by scheduling reinforcer delivery immediately after, and dependent upon, a response. The control exerted by this dependency is illustrated in a number of investigations in which the elimination of a previously established dependency of reinforcement upon a response resulted in decreases in rates of responding (Skinner, 1938; Zeiler, 1968). These results suggest that the effectiveness of reinforcement in maintaining behavior is related to the consistency with which it is dependent upon a response. Responding has been, however, systematically compared only at the two limiting values of the possible relations between responses and reinforcer delivery, *i.e.*, reinforcement either consistently response dependent or response independent. The present experiment provides evidence that, between these two limiting values, differ-

ent combinations of response-dependent and response-independent reinforcement affect responding in a graded manner.

METHOD

Subjects

Five mature White Carneaux pigeons with a history of responding on variable-interval schedules were maintained at approximately 80% of free-feeding weights.

Apparatus

The experiment was conducted in an operant conditioning chamber for pigeons with a work area 30 by 32 by 39.5 cm. The response key was located on the center of the work panel 22 cm from the floor of the chamber. It was transilluminated by a 28-V ac bulb at all times except during the delivery of reinforcers. A minimal force of approximately 0.14 N was required to operate the key. General illumination of the chamber was provided by a white 7-W 110-V ac bulb. Reinforcement was 3.0-sec access to mixed pigeon grain in a standard food magazine, the opening to which was on the center of the work panel, 8.5 cm from the floor. The opening was illuminated by a white 7-W 110-V ac bulb when the magazine was operated. White noise was continuously present in the chamber. Supporting relay circuitry and recording equipment were located in an adjacent room.

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Procedure

Each bird was first trained on either a variable-interval (VI) 60-sec (Birds 601 and 709) or a VI 100-sec schedule (Birds 581, 624, and 2162). The arithmetic (VI 60-sec) and constant probability (VI 100-sec) progressions provided by Catania and Reynolds (1968) were used to schedule the temporal distribution of reinforcer delivery. The tape programmer ran continuously during the session. When stable responding was observed, the schedule was changed to a variable-time schedule analogous to the variable-interval schedule, except that all reinforcers were delivered independently of key pecking. Each bird was then exposed to the sequences of different combinations of response-dependent and response-independent reinforcement shown in Table 1. The percent-

Table 1
Sequence of Experimental Conditions

Per Cent Response- Dependent Reinforcement	Number of Sessions				
	Bird 581	Bird 601	Bird 624	Bird 709	Bird 2162
100	26	35	33	23	25
0	30	24	21	27	33
10	13	12	12	18	13
33	12	13	12	24	10
66	—	20	—	—	—
100	12	12	12	24	12
66	—	16	—	—	—
33	—	20	—	10	—
10	9	12	1	18	—
0	—	20	—	6	—

age of response-dependent reinforcement in a session was varied by making every third, every tenth, or all reinforcer deliveries in a session response dependent. Thus, the effects of 100%, 33%, 10%, and 0% response-dependent reinforcement were investigated. In addition, Bird 601 was exposed to a 66% response-dependent reinforcement condition in which every third reinforcer delivery was response independent and the remainder were response dependent. Under all conditions, any scheduled response-dependent reinforcement had to occur before further response-independent reinforcers were delivered. Some combinations were studied for greater numbers of sessions than others to assess the stability of responding under the different combinations of response-dependent

and response-independent reinforcement. All sessions terminated after the delivery of 60 reinforcers.

RESULTS

Figure 1 provides the mean response rates during the last five sessions of each condition for each bird. Response rates were highest during the 100% response-dependent reinforcement condition and showed a systematic relation to the percentage of response-dependent reinforcement scheduled. The same general effects were obtained whether an ascending (0% to 100%) or a descending (100% to 0%) sequence was investigated. Rates of responding at each percentage of response-dependent reinforcer deliveries were stable after a few sessions; that is, no systematic decreases or increases in behavior were observed after the first few days of any particular condition. During the ascending sequence, Birds 709 and 2162 developed patterns of off-key pecking that seemed to interfere with recovery of the previously observed higher rates of responding in the initial baseline 100% response-dependent reinforcement condition. Table 2 provides the mean session durations of the last five sessions of each condition. The total amount of time required to deliver 60 reinforcers did not systematically change during the different experimental conditions.

Figure 2 illustrates the effects of the different percentages of response-dependent rein-

Table 2

Mean session duration in minutes during the last five sessions of each condition. The average interreinforcement interval was 60 sec for Birds 601 and 709, and 100 sec for Birds 581, 624, and 2162.

Per Cent Response- Dependent Reinforcement	Session Duration (min)				
	Bird 581	Bird 601	Bird 624	Bird 709	Bird 2162
100	103.81	61.9	103.8	59.0	103.7
0	100.6	58.9	101.2	59.0	100.6
10	99.1	60.4	97.1	59.0	97.7
33	98.4	59.8	97.9	60.3	97.6
66	—	58.3	—	—	—
100	97.8	58.9	96.4	59.0	96.9
66	—	58.9	—	—	—
33	—	57.7	—	58.7	—
10	97.9	58.5	97.8*	58.6	—
0	—	58.6	—	59.0	—

*one session

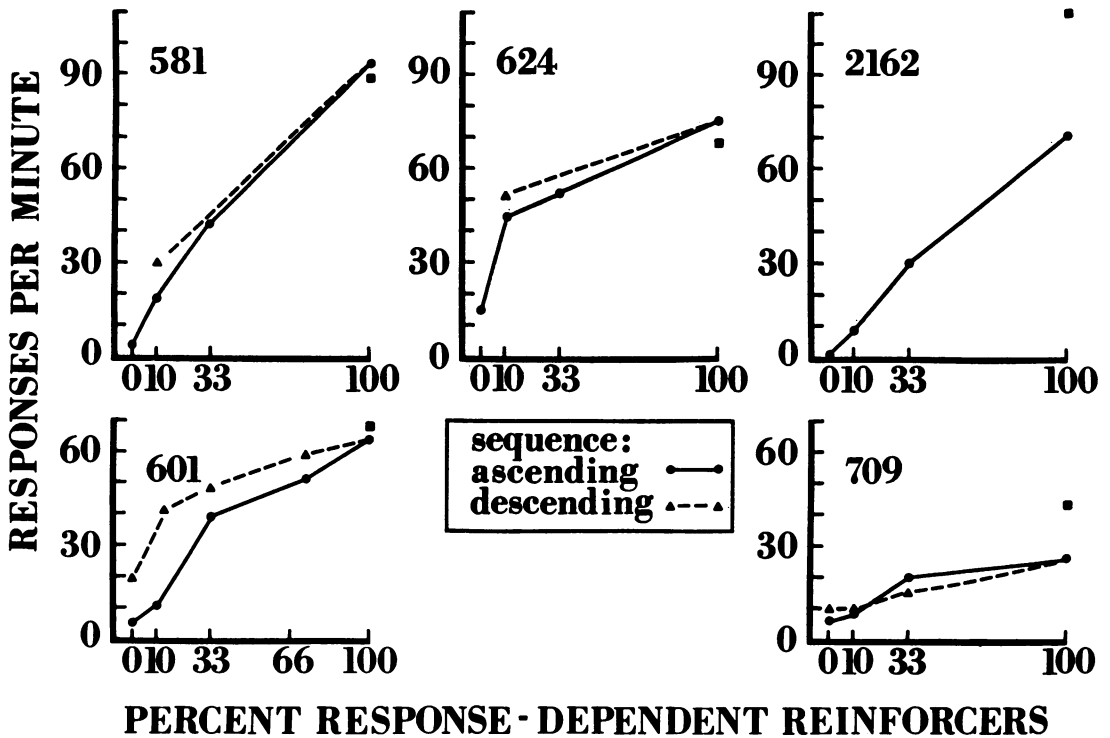


Fig. 1. Mean response rates of the last five sessions at each combination of response-dependent and response-independent reinforcer deliveries. The square symbol is the mean response rate during the last five days of variable-interval training. Ascending and descending refer, respectively, to sequences of 0% to 100% and 100% to 0% response-dependent reinforcer deliveries.

forcement on response rates within individual sessions. The fixed sequence of response-dependent and response-independent reinforcement had no systematic effects upon responding within the session. Responding was maintained at approximately the same rate throughout a session, and the mean rate during a session increased as the percentage of response-dependent reinforcement increased from 0 to 100.

DISCUSSION

Response-independent reinforcement sometimes maintains responding at nonzero rates for long periods of time (Herrnstein, 1966; Lattal, 1972). Other data, including that from Bird 2162 in the present experiment, suggest that responding is often transient and eventually ceases when reinforcement is response independent (Zeiler, 1968). The present data suggest that combinations of response-dependent and response-independent reinforcement may substantially increase rates and maintain

them at levels higher than are maintained when all reinforcement is response independent. These data are also in general agreement with the findings of an experiment that compared the behavior of rats during multiple and mixed schedules with response-dependent and response-independent reinforcement in the different components (Lattal, 1973). With half of the total reinforcer deliveries response dependent and half response independent, response rates in the response-independent component were low during the multiple schedules but higher and indistinguishable from the response rates in the response-dependent component during the mixed schedules. The present comparisons with Bird 601 between 66% and 100% response-dependent reinforcement suggest that the overall rates in the previous study might have increased if the mixed schedule with 50% response-dependent reinforcement were changed to one with 100% response-dependent reinforcement.

These data have several implications. First, the effectiveness of reinforcement in maintain-

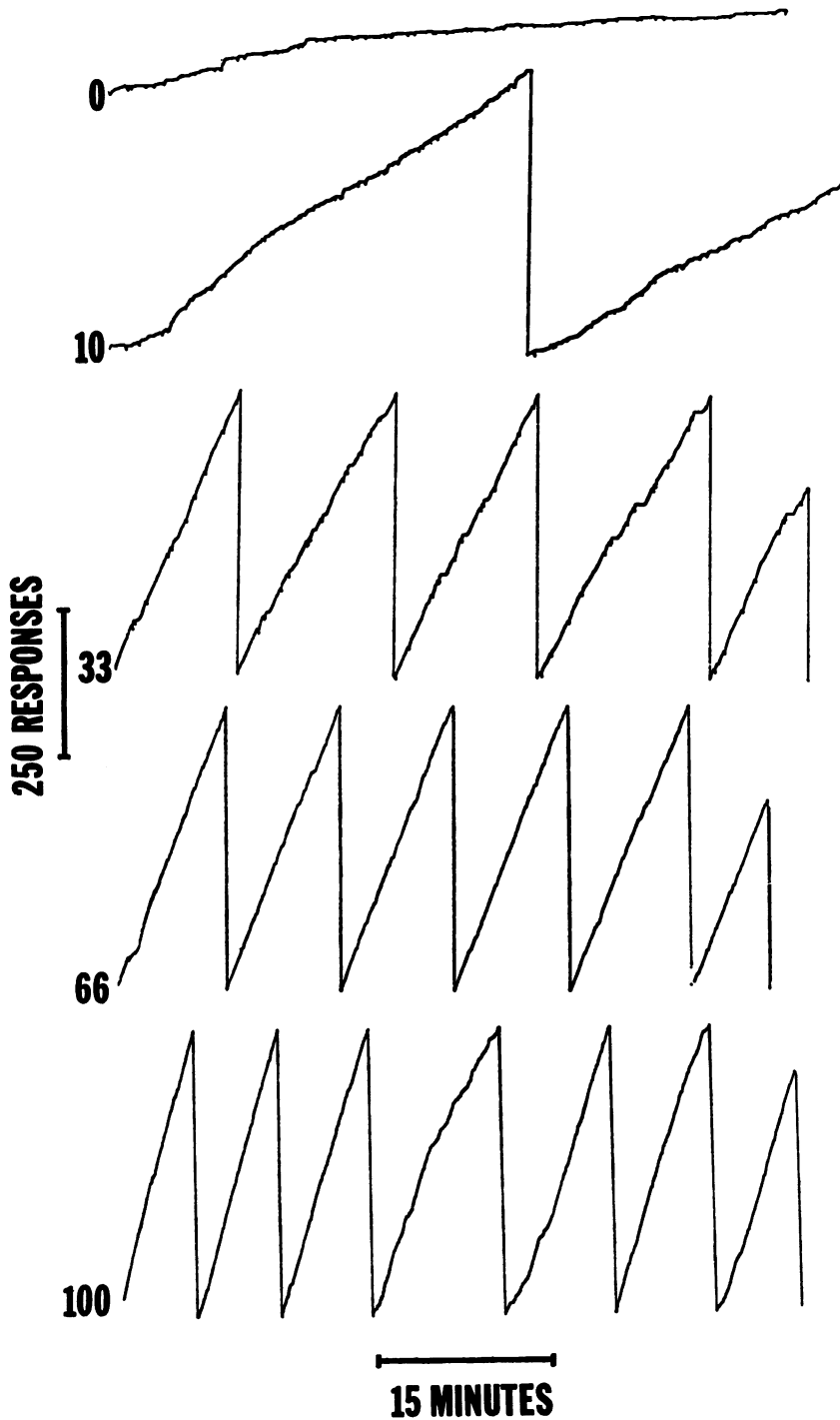


Fig. 2. Illustrative cumulative records of Bird 601 from each combination (ascending sequence) of response-dependent and response-independent reinforcement (indicated at the bottom-left corner of each record). Each record represents a complete session. Downward deflections of the pen indicate reinforcer delivery on the records from the 0%, 10%, and 33% conditions. Deflections were omitted on the 66% and 100% records. Beginning with the first downward deflection of the pen, every tenth and third deflection indicates the delivery of a response-dependent reinforcer in the 10% and 33% conditions, respectively. All other reinforcement was response independent.

ing behavior has been related to a number of parameters, such as the frequency and temporal distribution of reinforcement (e.g., Catania and Reynolds, 1968). Investigations of the parameters have been conducted utilizing schedules in which all reinforcement was response dependent. The demonstration of a functional relation between combinations of response-dependent and response-independent reinforcement and rates of responding suggests that the dependency between response and reinforcement is a parameter of equal importance in behavioral control to those previously investigated. Second, response-independent reinforcement has been used as a technique for maintaining constant reinforcement frequencies while reducing response rates, thereby separating the effects of these two variables (Halliday and Boakes, 1971). Difficulties with this procedure have been transient changes in response rates and an inability to maintain intermediate levels of responding between 0% and 100% response-dependent reinforcement to isolate the effects of different response rates. By utilizing combinations of response-dependent and response-independent reinforcement as described here, a much wider range of stable response rates may be obtained. Finally, combinations of response-dependent and independent reinforcement in applied settings where consistent control over the response-reinforcement dependency is not possible may be a useful procedure in maintaining relatively frequent responding.

Other experiments have utilized somewhat different procedures to determine the behavioral effects of combinations of response-dependent and response-independent reinforcement. The superimposition of a fixed-time schedule of response-independent reinforcement upon a fixed-ratio schedule resulted in the cessation of responding after several sessions (Edwards, Peek, and Wolfe, 1970). Rachlin and Baum (1972) superimposed different variable-time schedules upon a VI 3-min schedule with effects similar to those reported here. Rachlin and Baum's data were generated by varying both frequency of reinforcement and percentage of response-dependent reinforcement, while the present experiment varied only the dependency and held the frequency of reinforcement constant. Lattal (1973) maintained approximately equal rates of responding in both components of a mixed

schedule when 5-min components of VI and VT were randomly arranged.

In each of these experiments, response-independent reinforcement occurred even if a scheduled response-dependent reinforcement was available. In the present experiment, any scheduled response-dependent reinforcement had to occur before subsequent response-independent reinforcement. This procedure might independently have the effect of increasing response rates, since Neuringer (1973) found that pigeons will respond to produce periods of response-independent reinforcement. Such a procedure would affect behavior only if response rates were sufficiently low that the occurrence of response-independent reinforcement was delayed by the birds' failure to respond soon after response-dependent reinforcement was scheduled. Figure 1 shows that, even during the condition in which all reinforcement was response-independent, all birds except 2162 responded at rates higher than the minimal mean rate (once per minute for 601 and 709 and once per 100 sec for 581, 624, and 2162) necessary for scheduled response-dependent reinforcement to occur so that response-independent reinforcement was not delayed. More directly, the data in Table 2 show that session duration (and as a result, the occurrence of response-independent reinforcement) was not systematically affected by the addition of the contingency that scheduled response-dependent reinforcement occur before further response-independent reinforcement. It would therefore appear unlikely that the requirement of response-dependent reinforcement before further response-independent reinforcement systematically affected response rates.

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