

RESPONSE DECREMENTS PRODUCED BY EXTINCTION AND BY RESPONSE-INDEPENDENT REINFORCEMENT¹

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The effects of extinction and of response-independent (free) reinforcement in decreasing rates of key pecking by pigeons were compared in single schedule (Phase 1) and multiple (Phase 2) conditions. In both phases, response rates decreased more rapidly with extinction than with free reinforcement conditions. Behavioral contrast was obtained from subjects trained in a multiple schedule involving extinction in Phase 2, whereas subjects trained in a multiple schedule involving free reinforcement showed a slight negative induction effect. Whether subjects experienced extinction or free reinforcement under single stimulus conditions did not affect subsequent performance in the discrimination situation of the second phase. Disinhibition testing was carried out at the end of both phases, but there was no evidence for disinhibitory effects under any condition.

A number of recent studies have reported research on multiple schedules in which one stimulus is associated with response-dependent reinforcement and a second with response-independent reinforcement (Halliday and Boakes, 1971; Lattal and Maxey, 1971; Wilkie, 1972). Of major interest in these studies is the evidence they provide on behavioral contrast, since the situation is one in which changes of response rates occur while reinforcement rates remain constant. It is thus of potentially great importance for isolating the variables, for example, changes in reinforcement density and decreases in response rate, that are critical for the occurrence of behavioral contrast.

The available evidence indicates that when response rates in one component are reduced by the introduction of response-independent reinforcement no systematic changes in response rate occur in the other component. This implies that, in a situation in which response rate decreases after extinction is introduced would lead to the occurrence of behav-

ioral contrast in the other component, a similar decrease produced by free reinforcement would not do so. (The terms "response-independent" and "free" are used interchangeably here; for reasons given elsewhere (Halliday and Boakes, 1972), these are preferred to the "FT" and "VT" terminology suggested by Zeiler (1968)).

However, this implication cannot be made without reservation. This reservation is based on problems in interpreting various factors, such as different acquisition rates and the effects of pre-training, in previous studies. In Lattal and Maxey (1971) the four rats trained under *mult VI* Free VI conditions in Experiment 1 failed to show any consistent behavioral contrast; however, the authors did not report any contrast effects in Experiment 2 where three rats were trained in a similar situation under *mult VI* EXT conditions. Since behavioral contrast occurs less reliably with rats than with pigeons (*e.g.*, Pear and Wilkie, 1971), one cannot safely assume that in Experiment 1 behavioral contrast would have occurred under otherwise identical extinction conditions. The related experiment by Wilkie (1972) used four rats and a pigeon as subjects and included a *mult VI* EXT condition. Since this condition was introduced after the rats had already received at least 15 sessions of a discrimination involving free reinforcement, assessment of rate changes in the positive component under extinction conditions was based on baseline rates established at a considerably

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earlier time. This weakens the author's claim that the results unambiguously indicate behavioral contrast.

Pigeons were used as subjects in Halliday and Boakes (1971). In addition to finding an absence of contrast in subjects trained under free reinforcement conditions, it was found that subjects trained in an otherwise identical situation involving extinction did exhibit behavioral contrast. A slight, though not reliable, tendency was found for the discrimination to be learned more rapidly under extinction conditions than under free reinforcement conditions, despite a pre-training procedure intended to minimize such a difference. In a subsequent experiment (Halliday and Boakes, 1972, Experiment 2) this pre-training was omitted and the free reinforcement discrimination was learned considerably more slowly than that involving extinction. Comparisons between Experiments 1 and 2 in Lattal and Maxey suggest that this result also holds for rats.

The implications for the analysis of behavioral contrast to be drawn from multiple schedules involving extinction and free reinforcement are complicated if, as the above evidence suggests, a discrimination develops considerably more slowly under free reinforcement conditions, unless special pre-training methods are used. If this is the case, then differences in behavioral contrast effects may be a result of the difference in discrimination performance, where no pre-training is given, or to the differential effects of pre-training procedures, where these are used.

The present experiment was designed to investigate this problem by examining the way in which prior experience of free reinforcement or extinction affects subsequent performance in multiple schedules. In addition, the design made it possible (1) to make systematic comparisons between decrements in key pecking produced by the introduction of free reinforcement and those produced by the omission of reinforcement, and (2) to examine whether there is any relationship between the magnitude of behavioral contrast effects to one stimulus and the rate at which responding is reduced in the presence of a second stimulus.

The interest in comparing response decrements produced by the two procedures arises from the contrast between the literature on superstitious behavior, based mainly on studies

using pigeons (*e.g.*, Herrnstein, 1966), and the results obtained by Rescorla and Skucy (1969) using rats as subjects. The former suggests that free reinforcement produces a much more gradual decrease in responding than that produced by extinction, whereas Rescorla and Skucy found rather small differences that were most apparent in the final asymptotic levels of responding produced by the two procedures. The only direct comparison using key pecking by pigeons was made by Neuringer (1970) after subjects had made only three reinforced responses. Because of this brief history of response-dependent reinforcement, little can be inferred about the effects of the two procedures after considerable training has been given with response-dependent reinforcement, as in the study by Rescorla and Skucy and in the present experiment.

A further purpose of the present study was to investigate disinhibition effects in pigeons. Brimer (1970, 1972) reported extensive evidence for the disinhibition of lever pressing by rats. Tests for disinhibition were included in this experiment, following closely the procedure used by Brimer, to determine whether this phenomenon could be detected with pigeons following the extinction of key pecking, and also whether it occurred following response decrements produced by free reinforcement.

METHOD

Subjects

Sixteen male, adult homing pigeons were maintained at 80% of their free-feeding weights. Their prior experimental history was limited to an autoshaping procedure, using a white keylight, that was carried out in another chamber.

Apparatus

A standard pigeon chamber contained an end wall, painted matt black, on which a single response key was mounted centrally at a height of 8 in. (20 cm). An in-line display unit was used to transilluminate the key with either white or green (Wratten 61) light or to project a pattern of three vertical black lines on the green background. A Gerbrands grain hopper was mounted directly under the response key and a white bulb on the ceiling at the rear of the chamber was used as the houselight.

The chamber was contained within a sound-attenuating cubicle, in which white noise was present throughout all experimental sessions. An Aim-Bio solid state system was used to arrange experimental conditions.

Experimental Design

The procedure contained two distinct phases. Constant stimulus conditions were used in Phase 1 where responding was first established on a variable-interval schedule and then reduced either by omitting reinforcement (Extinction condition) or making its occurrence independent of responding (Free Reinforcement condition). When response rates had dropped to a criterion level a disinhibition test was given, which terminated this phase. Multiple schedules were used for the same subjects in Phase 2. Under both conditions of this phase, response-dependent reinforcement was available on a variable-interval schedule in the S_1 component, while in the S_2 component reinforcement was either omitted (Extinction condition) or response-independent (Free Reinforcement condition). On reaching a discrimination criterion in this phase, subjects were given a further disinhibition test and the experiment was terminated.

Two squads of eight birds were trained in succession and subjects were assigned to conditions such that four birds were exposed to each of the four combinations of conditions: Extinction-Extinction, Extinction-Free Reinforcement, *etc.* The sequence of procedures and assignment of subjects is shown in Table 1.

Phase 1 Procedure

The keylight was white throughout this phase. In this, and the following phase, reinforcement consisted of 4-sec access to grain, the houselight was on continuously (except when specified below) and six daily sessions were given each week. Once pecking was established, using an auto shaping procedure, the reinforcement schedule was progressively changed from CRF to a variable-interval schedule of mean 30 sec over a period of three sessions. Subsequently, a further eight sessions were given in which the VI 30-sec schedule was maintained.

On the sixth and seventh session of VI 30-sec training, half of the subjects were given a pre-test designed to assess the effects on maintained behavior of the stimulus to be used in

Table 1

Sequence of main conditions and assignment of subjects. The number of sessions in the initial test period in Phase 1 and the number of sessions of discrimination training in Phase 2 are indicated in parentheses after each subject.

Phase 1 (White key only)			
1. All subjects: VI 30-sec (eight sessions)			
FREE			
2. EXTINCTION		or	REINFORCEMENT
(Free VI 30-sec)			
P355 (1)	P179 (1)	P178 (3)	P349 (5)
P356 (1)	P348 (1)	P350 (4)	P352 (2)
P362 (1)	P354 (1)	P353 (2)	P361 (9)
P367 (1)	P365 (2)	P364 (4)	P366 (13)
3. All subjects: Disinhibition testing			
Phase 2 (S_1 : Green key; S_2 : Green key, plus vertical lines)			
4. All subjects: <i>mult</i> VI 30-sec VI 30-sec (six sessions)			
FREE			
5. EXTINCTION		or	REINFORCEMENT
(<i>mult</i> VI 30-sec EXT)			(<i>mult</i> VI 30-sec Free VI 30-sec)
P355 (5)	P178 (4)	P179 (10)	P349 (17)
P356 (6)	P350 (4)	P348 (16)	P352 (17)
P362 (4)	P353 (5)	P354 (13)	P361 (8)
P367 (5)	P364 (7)	P365 (9)	P366 (17)
6. All subjects (except P349, P352 and P366): Disinhibition testing (two sessions).			

the disinhibition test. Starting after 33 min on each of these sessions, the houselight was switched on and off for a period of 3 min at a frequency of 1.7 Hz with equal on- and off-durations.

Following the eighth session of VI 30-sec training, equal numbers of subjects were assigned to two conditions in such a way as to match response rates in the groups. During the testing procedure, the duration of each session was a maximum of 80 min. On the first test session the VI 30-sec schedule was maintained for the first 16 min and then for the rest of the session, and for subsequent test sessions, either reinforcement was omitted (Extinction condition) or free reinforcement was delivered at the same rate as before *i.e.*, a Free VI 30-sec schedule was introduced (Free Reinforcement condition).

When each subject reached a criterion of no responding in three successive 1-min periods, disinhibition testing was begun. The 3 min immediately following the criterion formed either a Stimulus period or a Dummy period. Subsequently, when the criterion was again reached the next 3-min period formed a Dummy period, if previously a Stimulus pe-

riod had occurred, or otherwise a Stimulus period. During Stimulus periods, the house-light was flashed as during the pre-test, while in Dummy periods no stimulus change occurred. Within each group, half the subjects received the Stimulus period first and the other half the Dummy period first.

Subsequently, subjects were given three re-training sessions on the VI 30-sec schedule, followed by a repeat of the testing procedure in which for each subject the order of Stimulus and Dummy periods was reversed.

Phase 2 Procedure

For a given subject there was a delay of 45 days on average between the end of Phase 1 and the beginning of this phase. During Phase 2, the keylights was green during S_1 periods and during S_2 periods vertical lines were projected on the green background. Responding to these stimuli was established using an auto-shaping procedure in which S_1 and S_2 occurred with equal frequency in the 5-sec periods preceding reinforcement. Each session contained 20 stimulus periods with a mean inter-stimulus interval of 30 sec and sessions were repeated until a subject responded.

On the following session, free-operant conditions were introduced. Each session contained 40 periods of 54 sec duration in which S_1 and S_2 occurred with equal frequency in semi-random order. These periods were separated by 6-sec blackouts. The reinforcement schedule associated with each stimulus was initially CRF and then, after 10 responses had been made to a given stimulus, a variable-interval of mean 30 sec.

Following six sessions of baseline training (*mult* VI 30-sec VI 30-sec) discrimination conditions were introduced. Response-dependent reinforcement continued to be available on the VI 30-sec schedule in S_1 periods, while in S_2 periods reinforcement was either omitted (*mult* VI 30-sec EXT) or presented independently of responding at the same rate as in S_1 periods (*mult* VI 30-sec Free VI 30-sec). Subjects were allocated to conditions as described above and in such a way that baseline rates were approximately matched for the two conditions. Discrimination training was continued for each subject until the mean S_2 response rate within a session was less than 10% of the S_2 baseline rate, where this was the median rate to this stimulus over the final five sessions

of baseline training. In the following two sessions, disinhibition testing was carried out while the discrimination conditions were maintained.

The stimulus used for disinhibition testing was the same as in Phase 1, namely the house-light flashing at 1.7 Hz. With Test Sequence A, this was presented throughout the tenth and twentieth S_1 periods, and the eighth and eighteenth S_2 periods. With Test Sequence B, it was presented on the fifth and fifteenth S_1 periods, and the third and thirteenth S_2 periods. The Stimulus periods in one sequence were pre-selected as Dummy periods for the other sequence. Thus, for example, with Sequence A the number of responses occurring with the house-light flashing in the eighth and eighteenth S_2 periods was compared to the number of responses in the third and thirteenth S_2 periods. Each subject was given both sequences on successive sessions and order was counterbalanced within groups.

RESULTS

Phase 1

Response rates decreased more rapidly under extinction than under free reinforcement conditions. The Extinction group reached the criterion first on average after 42 min and then, following re-training, after 21 min. The comparable results for the Free Reinforcement group were 371 and 226 min. The differences between the groups were highly reliable: the slowest subject in either Extinction test reached criterion sooner than the fastest subject in either Free Reinforcement test (Mann-Whitney, $p < 0.001$ for each test). There was also a reliable decrease in time to criterion from the first to the second test in the Extinction group (t-test, 1-tail, $p < 0.025$), but the difference between the two tests for the Free Reinforcement group was not significant ($p > 0.05$).

In a similar comparison with rats, Rescorla and Skucy (1969) found that the most marked difference between the two procedures was in the final asymptotic level that they maintained. Therefore, the large difference between the groups that was obtained here may possibly have been due to the use of a severe criterion, which Free Reinforcement subjects met only when they had already reached asymptote. Consequently, a less stringent cri-

terion would have produced a smaller difference between the groups. To check this possibility, the form of the response decrements under the two conditions was examined. Since the range of times to criterion was very large, this was done by taking average response rates over successive tenths of the time to criterion for each subject (following Vincent, 1912), as shown in Figure 1. It can be seen that there is little difference between the averaged functions for the two conditions, thus suggesting that the choice of criterion had little effect on the above results.

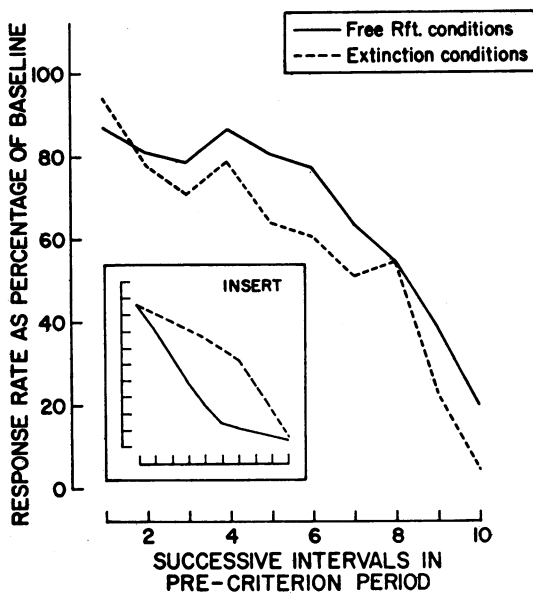


Fig. 1. Vincentized functions for the response decrements in Phase 1. For each subject the time to criterion was divided into 10 equal segments and the average rate of responding within a segment was expressed as a percentage of the median response rate in the final three sessions of variable-interval training. These functions show the percentage in each segment averaged over the eight subjects run under each of the two conditions. The hypothetical functions shown in the insert illustrate the kind of result that would have been obtained if the major difference had been in the asymptotic level of responding.

The possibility of a relationship between prior response rate and the subsequent decline in responding was examined; it was expected that, if adventitious reinforcement contingencies were important, the introduction of free reinforcement would have a more immediate effect on subjects with an initially low response rate. However, no reliable correlation between baseline rates and time to criterion was found

in either group; in fact the rank order correlation was higher for Extinction conditions (+0.45) than for Free Reinforcement conditions (-0.07).

Flashing the houselight was reliably effective in suppressing responding during the pre-tests. Each of the eight subjects responded less in the presence of this stimulus than during the comparable preceding interval in the first pre-test and the same was true of most subjects (six of eight) in the second pre-test². When the same stimulus was presented after response rates had fallen to the criterion level there was no evidence that it had a disinhibitory effect in either condition. Since each subject received two tests, there was a total of 16 tests under each condition. Under Extinction conditions, there were two cases in which more responding occurred in Stimulus than in Dummy periods, four cases of less responding and in the remainder (10 of 16) no response occurred in either period. Under Free Reinforcement conditions, there were seven cases of increased responding to the stimulus, eight of decreased responding and in the remainder (one of 16) no response in either period.

Phase 2

In discrimination training, response rates in S_2 declined more rapidly under Extinction than under Free Reinforcement conditions. The criterion level of 10% of the baseline rate was reached after a median of five sessions by the Extinction subjects and 14.5 sessions by the Free Reinforcement subjects. There was no overlap on this measure (Mann-Whitney, $p < 0.001$) and no suggestion that experience in Phase 1 affected these scores in either group. Training was discontinued for three Free Reinforcement subjects when they failed to reach criterion after 17 sessions.

Since the results obtained under Free Reinforcement conditions are of particular interest, the individual data for each subject in this group are shown in Figure 2. As in previous studies (*e.g.*, Halliday and Boakes, 1971) the decrease in S_2 rates was not accompanied

²Brimer (1972) expressed the results of his similar pre-tests in terms of Kamin's (1965) suppression ratio, $A/A + B$, where A represents the number of responses in the test, or stimulus, period and B the number of responses in the equivalent preceding interval. In the present study, the average suppression ratio was 0.20 in the first and 0.33 in the second pre-test.

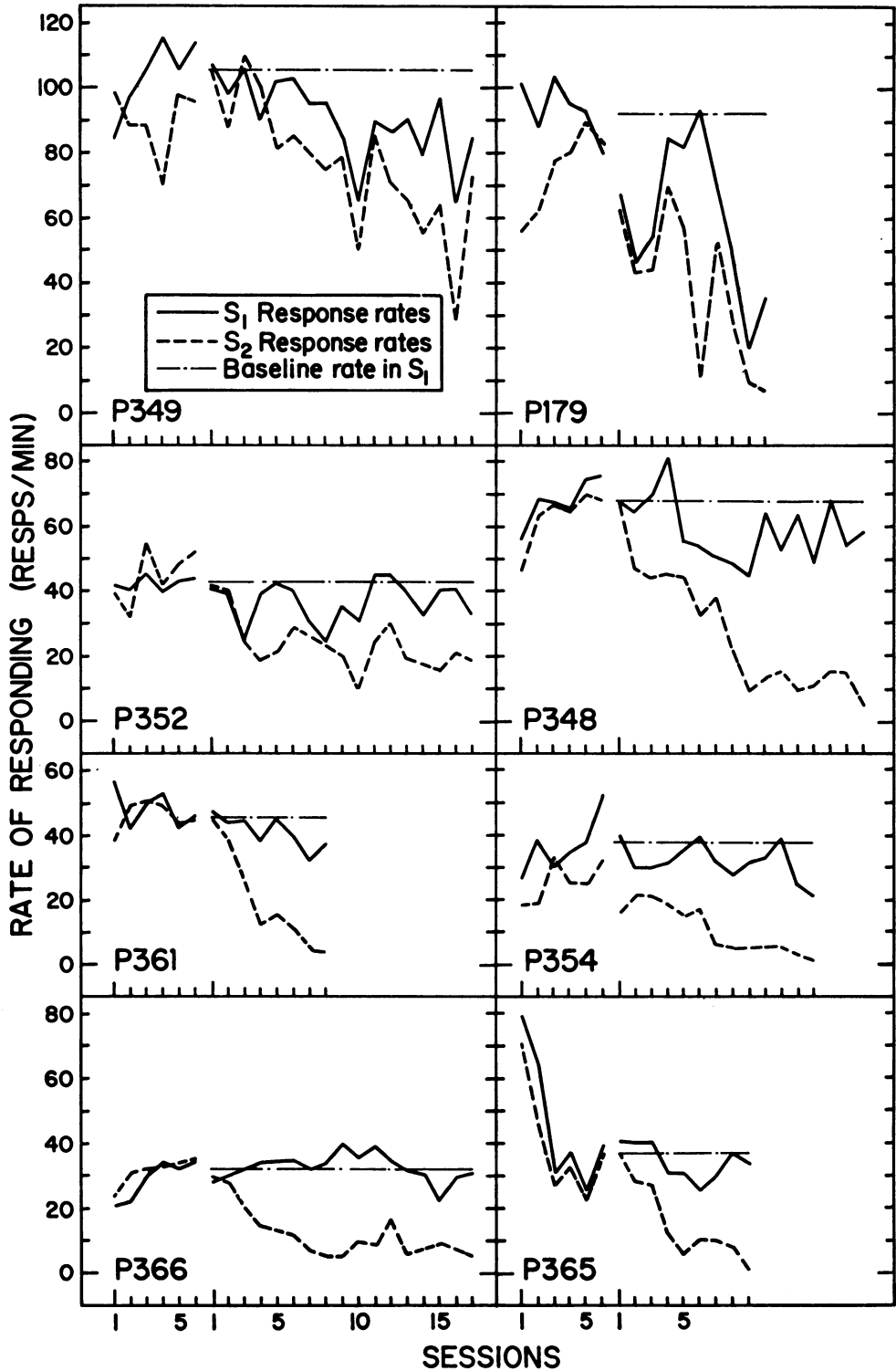


Fig. 2. Response rates in S₁ (green) and S₂ (green plus vertical lines) for subjects trained on the *mult* VI 1-min Free VI 1-min schedule in Phase 2. Subjects with prior experience of free reinforcement in Phase 1 are shown on the left-hand side and those with extinction conditions in Phase 1 on the right-hand side.

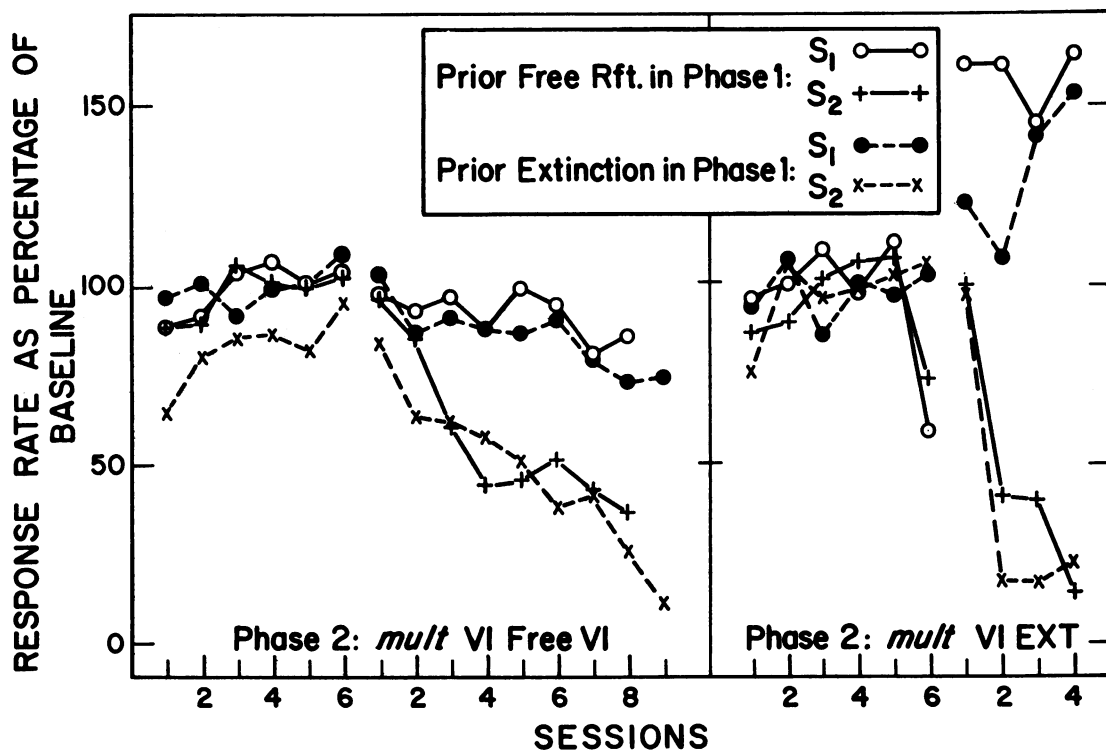


Fig. 3. Median rates of responding in Phase 2 relative to baseline response rates. Performance under free reinforcement conditions is shown in the left-hand panel and under extinction conditions in the right-hand panel. For each subject, response rates to S_1 and S_2 in a given session were expressed as percentages of baseline rates to the stimuli and the median value within each group of four subjects (Free reinforcement- Free reinforcement; Extinction-Free reinforcement; *etc.*) is shown here.

by a behavioral contrast effect in the S_1 component. Contrast did reliably occur in the Extinction subjects, as is shown in the comparison between the conditions in Figure 3. Statistical analysis of the differences in S_1 performance was based on a contrast ratio, defined as the ratio between the median S_1 response rate over the first four discrimination sessions (as three Extinction subjects reached criterion in the fourth session) and the baseline S_1 response rate. The median value for the Extinction subjects was a ratio of 1.51 and for the Free Reinforcement subjects 0.98. A two-way analysis of variance based on these ratios showed a reliable effect of Phase 2 conditions ($F_{1,12} = 16.8$, $p < 0.01$), but no Phase 1 or interaction effect ($p > 0.10$).

Since it appeared that the magnitude of behavioral contrast under *mult VI EXT* conditions (in terms of ratios) was greater for subjects with low baseline response rates, analysis of a possible relationship between S_2 decrements and changes in S_1 response rates was

performed separately for subjects with high (> 40 resps/min) and low baseline rates of responding. This analysis is shown in Figure 4, where equivalent data from Halliday and Boakes (1971, 1972) are also included. It can be seen that there is no suggestion of greater contrast effects with subjects that display a rapid decrement in S_2 responding. It should also be noted that on the measure employed in this analysis, not only is there overwhelming evidence for behavioral contrast in Extinction subjects (all 14 with an index greater than 1.0), but there is also evidence for a small negative induction effect under Free Reinforcement conditions, in that the majority of these subjects (12 out of 16) have an index less than 1.0 (*t*-test, 1-tail, $p < 0.05$).

As in Phase 1, the disinhibition tests did not reveal any tendency for the flashing house-light to increase responding. Of the 16 tests with Extinction subjects, in one case there were more responses in the Stimulus periods than in the Dummy periods, in 11 cases fewer

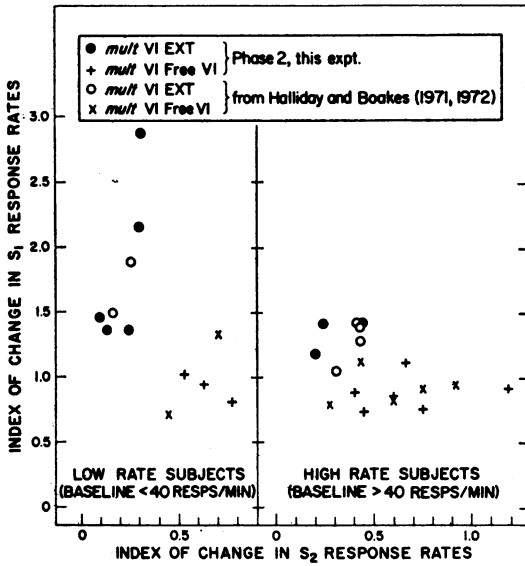


Fig. 4. Changes in S_1 response rates as a function of decrements in S_2 response rates. The index for S_2 is the ratio between the average S_2 response rate in the third and fourth discrimination sessions and the S_2 baseline rate; similarly, that for S_1 changes is the ratio between average S_1 response rates on those sessions and the S_1 baseline rate. Equivalent data are also included for all subjects in Halliday and Boakes (1971, 1972).

responses, and in the remainder (four of 16) there were no responses in either period. Similarly of the 10 tests with Free Reinforcement subjects there were two cases of increased responding in the Stimulus periods, six cases of decreased responding and in the remainder (two of 10) either zero or equal responding in both periods.

DISCUSSION

The main results of the present study are: (1) that response rates decrease more slowly following introduction of free reinforcement than following the omission of reinforcement, both in single and multiple schedules; (2) that in a situation in which behavioral contrast was obtained under *mult VI EXT* conditions, a slight negative induction effect was obtained under *mult VI Free VI* conditions; and (3) that prior experience of extinction and of free reinforcement do not have differential effects on subsequent performance on multiple schedules that include either extinction or free reinforcement components.

The results support the conclusion, discussed earlier, that free reinforcement condi-

tions do not produce the behavioral contrast that would occur in an otherwise identical situation involving extinction. There are a number of points supporting this conclusion. First, previous evidence (Halliday and Boakes, 1971) cannot be explained in terms of a possible differential effect in the discrimination condition of pretraining with a free reinforcement schedule. Second, the difference cannot be attributed to differential rates of acquisition, because there was no indication in the present experiment, or in the different kind of analysis reported by Terrace (1972), that subjects whose response rate to the S_2 stimulus decreases slowly in a *mult VI EXT* schedule show less contrast than those whose rate drops rapidly. Finally, at an early stage of discrimination training, where there is considerable overlap in the S_2 decrements that have taken place, the difference in S_1 rates is already apparent (see the analysis of performance in Discrimination Sessions 3 and 4 for high-rate subjects in Figure 4).

The finding that response rates decline more slowly with the introduction of free reinforcement than with the introduction of extinction is consistent with previous evidence (Neuringer, 1970; Rescorla and Skucy, 1969). However, the magnitude of the difference found in Phase 1 is considerably greater than in the comparable experiment by Rescorla and Skucy, in that a ratio of the order of 10:1 was found here which, as shown above, was not attributable to differences in asymptotic level of responding. The difference in magnitude may of course be due to a variety of procedural and species differences; an interesting possibility is that the main factor was the difference between the "spaced" testing employed by Rescorla and Skucy (1969), in that they measured number of responses occurring in each daily session, and the "massed" testing employed here. They note that greater spontaneous recovery occurred at the beginning of each session under extinction conditions. Because most subjects in the extinction conditions in Phase 1 of the present experiment reached the criterion within the first session, this possible factor could not affect the results found here. This factor might explain why the difference in decrements produced by extinction and free reinforcement, though equally reliable, were less dramatic in Phase 2, where "spaced" conditions obtained. On other grounds, the main-

tenance of responding by reinforcement in the other component might have been expected to exaggerate the difference by, for example, maintaining reinforcement as a cue for responding.

Given that both conditions represent a state in which responses have no effect on an animal's environment, why does extinction produce faster decrements than free reinforcements? A number of alternative factors have been suggested; it is possible that more than one of these is effective and some may be indistinguishable empirically. They include: (1) the *maintenance* of responding by adventitious contingencies of reinforcement, "superstitious" reinforcement (Skinner, 1938; Herrnstein, 1966; Neuringer, 1970); (2) the *elicitation* of responding by reinforcement, on both a conditioned and unconditioned basis (Rescorla and Skucy, 1969); (3) maintenance of incentive motivation by free reinforcement (Rescorla and Skucy, 1969); and (4) the operation of an inhibitory process (Halliday and Boakes, 1972) or "active inhibition" (Terrace, 1972) under extinction conditions, but not under free reinforcement conditions.

Rescorla and Skucy have presented impressive evidence for the importance of response-eliciting aspects of reinforcement and against the view that responding is superstitiously maintained, once a sizeable decrement has occurred. One source for this view is derived from their Experiment 2, where the amount of responding with free reinforcement was found not to depend on the prior level of responding produced by different exposures to extinction conditions, and this is supported by the present failure to find any relationship between baseline response rates and time to criterion.

It is not clear how one would evaluate the third factor listed above, the maintenance of incentive motivation, or how one would distinguish this from, say, the response-eliciting aspects of reinforcement. Assessment of the fourth possible factor, the operation of an inhibitory factor in extinction, requires further research on "spontaneous recovery" and "disinhibition" following the two procedures.

In this context, it is unfortunate that the present disinhibition tests produced no results. The reasons for this failure are unclear, since the procedure was directly modelled on that used by Brimer (1972) with consistent success:

a similar extinction criterion was used and the stimulus was one that his results indicate should produce disinhibition.

Greater understanding of disinhibition effects and further research into the question of whether they occur after response decrements produced by free reinforcement are particularly important in view of the main result of this study; namely, the firm conclusion that a response decrement produced by free reinforcement in one component of a multiple schedule is not accompanied by the behavioral contrast effect in the other component that would occur if the decrement had been produced by extinction.

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