

SECONDARY EXTINCTION OF LEVER-PRESSING BEHAVIOR IN THE ALBINO RAT¹

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Interest has recently been revived in the problem of latent, or secondary extinction,³ a problem which may be formulated: If an instrumental response (R) has been conditioned to a stimulus (S_o) by following the occurrence of R in the presence of S_o with a reinforcing stimulus (S^r), and if the reinforcement value of S^r is subsequently modified, will the response to S_o remain unaffected or will it have altered in accordance with the new reinforcement value of S^r? Existence of secondary extinction would seem to imply that instrumental behavior involves a mediation process whose behavioral effects are governed by those of the reinforcer through which the behavior is established (11).

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³The title, "nonresponse-extinction" has been proposed by Deese (4) for this design. However, this is also appropriate to extinction procedures (e.g., drug-induced response blockade) considerably different from the present paradigm. Nor is the term "latent extinction" quite appropriate here, since there is no period during which the extinction is latent in the usual sense of the word. The term "secondary extinction" is here offered in analogy to "secondary generalization," a phenomenon of similar theoretical import (see 11).

Other than Miller's (9) demonstration that shocking rats placed directly in a distinctive goal box tended to suppress a running response which had previously terminated in that goal box, evidence either for or against secondary extinction is surprisingly meager. Seward and Levy (12) and Deese (4) have reported positive findings, but both experiments are complicated by a differential secondary reinforcement of experimental and control groups (2, 10), an effect whose importance has clearly been shown by Moltz (10), who was unable to demonstrate positive results in its absence, and also more recently by Coate (3). Negative findings have been reported by Bugelski, Coyer, and Rogers (2) and by Scharlock (13), but since these experiments also failed to show a secondary reinforcement differential which should have appeared, their significance is problematic.

The possibility of secondary extinction is here explored in thirst-motivated lever pressing of the albino rat. Such behavior, aperiodically reinforced by water reward, may somewhat arbitrarily be analyzed as a response chain of three main links: (a) lever pressing, (b) approach to the water cup, and (c) drinking. Stimuli accompanying water delivery ("magazine stimuli") serve to reinforce lever responses and provide discriminative cues for approach to the water cup (see 5). The question then arises whether, after the lever habit is established, altering the secondary reinforcement value of the magazine stimuli affects the strength of the lever habit prior to culmination of the response in the modified secondary reinforcement. The reinforcement properties of magazine stimuli may be altered, while levers are absent, in at least two ways ("magazine reconditioning"): (a) extinction of positive value through repeated activations of

the dry water magazines (Exp. I); or (b) endowment with secondary aversive properties by pairings of magazine stimuli with shock (Exp. II). The extent, if any, to which magazine reconditioning has weakened lever responding may then be determined by replacing the levers and comparing experimental and control groups for unreinforced lever presses ("lever extinction"). Whether magazine reconditioning was, in fact, accomplished may subsequently be tested by reconnecting the dry water magazines to the levers. Comparison of additional lever presses ("magazine extinction") reveals the residual reinforcement properties of the magazine stimuli.

EXPERIMENT I

Method

Subjects.—The Ss were male albino rats of the Sprague-Dawley strain. All were about 100 days old and experimentally naive at the beginning of the experiment. Forty Ss were given initial training, from which two matched groups of 16 Ss each were selected at the beginning of magazine reconditioning.

Maintenance and running schedule.—The Ss were run daily for a 20-min. recorded interval, plus about 1½ min. both before and after the interval recorded. They were always run under a 23-hr. water deprivation, water being received once a day for a period of 25 min. beginning 25 min. after return to the home cage. Dry food pellets were always available in the home cage.

Apparatus.—The Skinner boxes were a battery of eight in regular use at the University of Chicago. These boxes are sound and light insulated, with electrifiable grill floors. The water delivery mechanism consists of a small cup which dips into an underlying reservoir when activated. A single horizontal T lever is located above and 3 in. to the right of the water cup. Throughout the present experiment, reinforcement was controlled through a timing device which makes reinforcement available on a prearranged semi-random interval schedule. For the rates at which lever pressing stabilized, the schedule used furnished an average of one reinforcement for seven lever presses. Activation of the water magazine produced two prominent clicks, over-all duration of which was approximately .5 sec. In addition, a small, dim,

neon bulb to the left of the water cup flashed on for .1 sec. at the beginning of magazine activation.

Pretraining.—For the first six days of training, Ss were run with disconnected levers to familiarize them with the apparatus and provide a record of unconditioned operant lever-pressing level. The latter variable showed little or no relation to subsequent behavior measures.

Conditioning.—Three types of training were given during conditioning. (a) On 20 "lever conditioning" days (L), levers were connected to the full water magazines, with reinforcement available on the schedule reported. (b) On each of eight "magazine conditioning" days (M), levers were removed and magazines were activated by E, 20 activations per S on each of the first four days and 10 per S on each of the last four. The purpose of M was to establish and maintain the secondary reinforcement value of magazine stimuli independently of lever presence. (c) On five "adaptation" days (A), levers were removed and no reinforcements were given. This was to sharpen discrimination of lever stimuli as the essential S^D's for lever pressing. The sequential order of training was: 4M, 4L, M, 4L, M, 2L, 5A, 2L, M, 4L, M, 4L. An average response rate of around 200 lever responses per run was achieved by the fifth L day, gradually increasing to a daily mean of 250 presses, averaged over the last four days. There was little inter-S variation in total number of reinforcements, and later statistical analysis revealed no correlation between this variable and other behavior measures.

Magazine reconditioning.—After Day 20 of lever conditioning, an experimental and a control group of 16 Ss each were selected, closely matched for terminal response output, as measured by the last four days of conditioning. With levers removed, the experimental group then received a total of 400 activations of the dry magazine, distributed over 25 runs in the sequence: 40, 40, 0, 40, 40, 0, 0, 20, 20, six days not run, 40, 20, 20, 0, 20, 20, 0, 0, 20, 20, 0, 0, 0, 20, 20. Spacing of extinction was designed to encourage spontaneous recovery and subsequent re-extinction. Control Ss were treated during magazine extinction exactly as were the experimentals except that controls received no magazine activations and hence no extinction of the positive secondary reinforcement value of magazine stimuli.

Lever extinction.—Both groups were then run for 16 days with levers replaced but disconnected from the water magazines. By the end of this time, response rates had returned to their original unconditioned operant level.

Magazine extinction.—All Ss received a terminal eight runs wherein levers were recon-

nected to the dry magazines, with magazine stimuli contingent upon lever pressing according to the same schedule encountered during conditioning.

Results and Discussion

Examination of Fig. 1 reveals the course of response output during lever extinction to be practically identical for both groups, with the experimentals, contrary to hypothesis, actually showing a greater total output than controls. (The unusually large difference on Day 14 was primarily the contribution of a single S, who responded in a highly atypical manner that day.) The only evidence remotely favoring the existence of a stronger response tendency in the control group is its slightly greater output for the first two days. To test the significance of this, the sum of the first two days' output was subjected to an analysis of covariance (14, p. 378 ff.), even though *post hoc* selection of variables in this way biases statistical tests toward spurious significance. When the regression of the first two days' lever extinction output on terminal

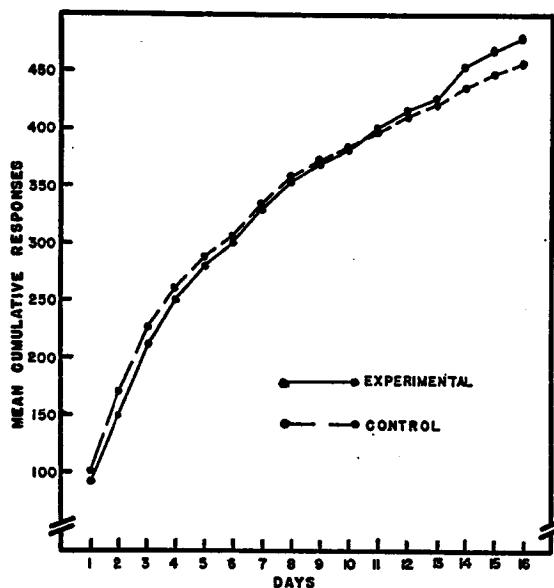


FIG. 1. Cumulative mean lever responses during "lever extinction" in Exp. I.

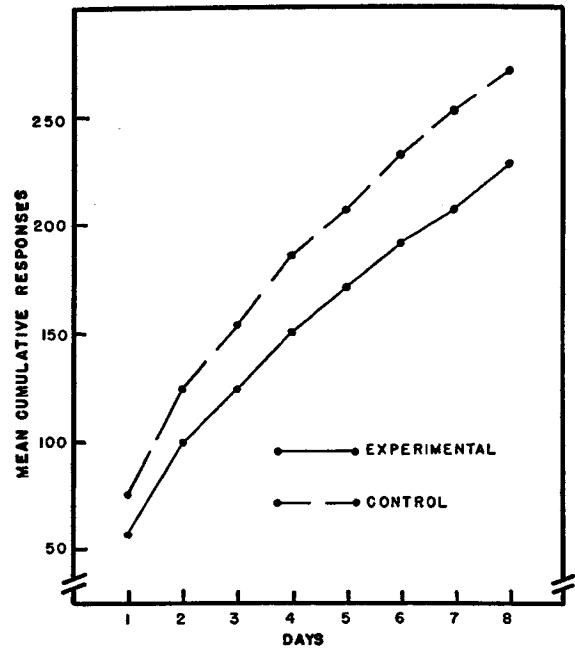


FIG. 2. Cumulative mean lever responses during "magazine extinction" in Exp. I.

conditioning rate is accounted for ($r = .54$), the ratio of between-group to within-group variance is $F = .96$, which occurs under the null-hypothesis with probability $P = .36$ (1 and 29 *df*). During magazine extinction (Fig. 2), however, a consistent difference appears. Analysis of covariance applied to the first day's output gives $F = 7.00$ ($P = .01$, 1 and 29 *df*). Thus, while there is no detectable difference between experimental and control groups in lever extinction outputs, reintroduction of magazine stimuli contingent upon lever pressing reveals clearly a greater residual reinforcement value of magazine stimuli for control Ss.

It would appear that under the parameters of this experiment, at least, partial extinction of a secondary reinforcer with whose aid an instrumental response has been established has no effect on the strength of the habit. It might be protested that the secondary reinforcers were insufficiently extinguished for the experimental group to display a detectably weakened habit, for magazine

TABLE 1
MEASURES OF PERFORMANCE, EXPERIMENTS I AND II

Group	N	Terminal Cond. Rate		First 2 Days Lever Extinction			Total Lever Extinction			First Day Magazine Extinction		
		Mean	SD	Mean*	SD	Adj. SD†	Mean*	SD	Adj. SD†	Mean*	SD	Adj. SD†
Experiment I												
E	16	241.2	63.1	150.6	53.6	50.2				57.0	22.2	22.6
C	16	240.7	62.9	169.1	68.4	58.8				75.9	19.1	18.6
Experiment II												
E	22	242.8	80.7	107.8	44.1	42.3	236.9	87.8	84.2	37.6	35.3	—
C ₁	16	245.4	76.0	121.4	36.6	32.7	272.4	64.8	61.3	93.9	31.2	25.2
C ₂	16	244.8	82.7	108.5	43.2	34.0	231.1	101.8	83.6	73.5	25.2	22.3

* Since groups were matched for terminal conditioning rate, adjusted means differ only insignificantly from observed means.

† Best estimate of parametric SD after removal of variance component attributable to terminal conditioning rate.

reconditioning produced a reinforcement loss of only about 25% (based on total responses during magazine extinction less an operant level base line of 10 responses per day), even though Beckwith's data (1) suggest that less than half this number of dry magazine activations following lever responses would have been ample for complete extinction. The fact remains, however, that the reinforcement difference, though small, was still large enough to be clearly evident statistically. There is no apparent reflection of this difference during lever extinction, and it must be concluded that the strength of a lever habit is at best quite insensitive to changes in reinforcement value of the stimuli by which the habit was initially reinforced, at least under the present parameters of conditioning.

EXPERIMENT II

Experiment II was conducted in the hope that the behavioral effect of a secondary reinforcer could be altered more radically by pairings with a primary aversive stimulus, and hence more likely reveal secondary extinction if this phenomenon exists.

Method

Subjects.—The Ss were similar to those of Exp. I, a total of 54 being used. No Ss were lost or discarded during the experiment.

Apparatus, maintenance, and running schedule.—Identical to Exp. I.

Pretraining and conditioning.—Treatment of Ss in Exp. II for these phases was, with three minor exceptions, identical to that of Exp. I: (a) Ss were given only four pretraining runs; (b) only three days of magazine conditioning were given prior to the first day of lever conditioning; and (c) to facilitate later discriminations, on each of the last four magazine conditioning days, all Ss also received 10 presentations of the tone later experienced by Group C₁ during magazine reconditioning. The mean daily response output over the last four days (terminal conditioning rate) was 244, very similar to the corresponding rate in Exp. I.

Magazine reconditioning.—The Ss were then divided into three groups closely matched for terminal conditioning rate; an experimental group (E) of 22 rats, and two control groups (C₁, C₂) of 16 rats each. As in Exp. I, levers were absent throughout magazine reconditioning, and the water magazines were always dry.

During the first four days, each S in Group E received 120 presentations of the dry water magazine, 40 on each of the first two days and 20 on each of the others. Groups C₁ and C₂ were run as usual, but received no magazine stimuli. During the next 22 runs, each S of

every group received a total of 40 electric shocks. The number of shocks varied from day to day according to the sequence: 3, 2, 4, five days not run, 3, 1, 2, 4, 0, 0, 4, 2, 0, 3, 0, 1, 2, 1, 0, 0, 4, 4, 0. The shock circuit was set to deliver an alternating current of approximately 1.0 ma. for .2 sec., automatically timed. For Group E, each shock was preceded by activation of the dry water magazine, with an automatically timed interval of .5 sec. between cessation of magazine stimuli and onset of shock. Group C₁ had each shock preceded by a medium intensity, 1000-cps tone, of .5 sec. duration and with an interval of .5 sec. between tone offset and shock onset. Group C₂ received shock alone, unheralded by any warning signal.

Lever and magazine extinction.—As in Exp. I, all Ss were now run with levers replaced, but disconnected. When lever extinction outputs appeared asymptotically equal for all groups, the dry magazines were reintroduced for seven days of magazine extinction.

Results and Discussion

Although the response outputs of Groups E and C₂ during lever extinction can scarcely be distinguished in Fig. 3, the record of C₁ shows a distinct superiority. To test the statistical significance of this difference, two preselected measures—sum of

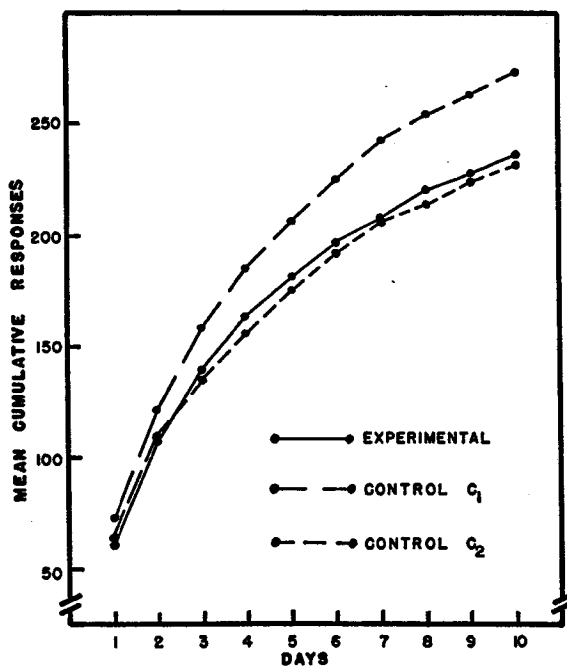


FIG. 3. Cumulative mean lever responses during "lever extinction in Exp. II."

responses for the first two days and total lever extinction presses—were separately subjected to an analysis of covariance in order to control for the variance component attributable to terminal conditioning rate, upon which the groups were matched. The between-group to within-group variance ratio for Groups E and C₁ in total lever extinction output is $F = 1.98$, which, for 1 and 35 *df*, gives $P = .20$ that this great a mean difference could have occurred by chance. For the total lever extinction output of Groups C₁ and C₂, $F = 2.46$, for which $P = .14$ ($df = 1$ and 29). The corresponding chance probabilities of the differences in the first two days of lever extinction are somewhat higher ($P = .32$ and $P = .30$, respectively). The data thus fall short of conventional statistical significance and do not warrant the conclusion that the theoretical populations, of which E, C₁, and C₂ are samples, differ in lever extinction output. However, neither do these data support the conclusion that there are no genuine group differences, for failure to reject the null-hypothesis is not in itself grounds for its acceptance, and the observed differences are too large to be completely ignored. Under the null-hypothesis, a difference between C₁ and E as large as the one observed and in this direction, as predicted, would be expected only once in ten, which, in the absence of further evidence, is a precarious statistic upon which to rest the conclusion that Groups E and C₁ did, in fact, show equal parametric response tendencies during lever extinction. Of much less ambiguous interpretation are the differences during magazine extinction (Fig. 4), as revealed by analysis of the first day's outputs. Covariance analysis yields a between-group to

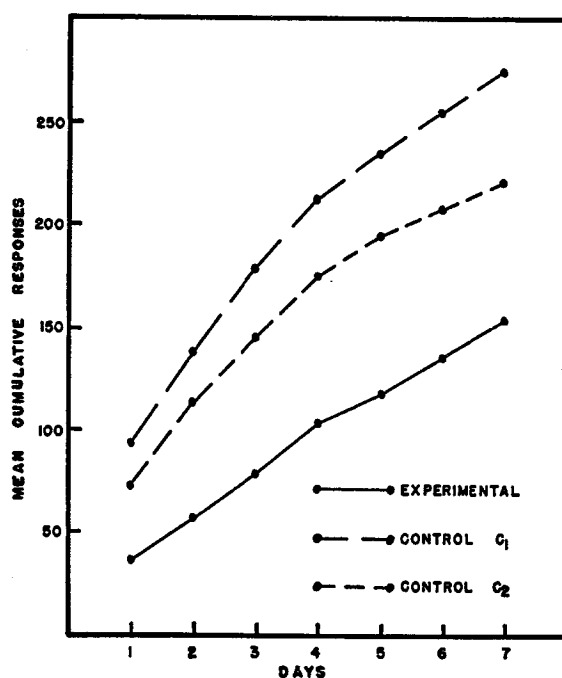


FIG. 4. Cumulative mean lever responses during "magazine extinction" in Exp. II.

within-group variance ratio of $F = 5.65$ for Groups C_1 and C_2 , for which $P = .02$ ($df = 1$ and 29), while a χ^2 comparison of scores dichotomized at the common median reveals the inferiority of E to be highly significant ($P < .001$).

Before these results can be evaluated, it is necessary to judge the extent to which comparison of lever extinction outputs is here a fair comparison of response tendencies. As in Exp. I, the only external stimuli present during lever extinction with contingency histories differing among the groups were the general environmental stimuli. In contrast to Exp. I, however, there is substantial empirical evidence from which here to anticipate differences in lever extinction outputs due to environmental stimuli alone, irrespective of any additional secondary extinction effects. It is a solidly established fact (e.g., 7) that stimuli associated with aversive stimuli in the Skinner box subsequently suppress lever pressing. (A plausible explanation is that such stimuli, having become secondarily aversive through type-S con-

ditioning, now elicit "anxiety" responses—crouching, defecating, etc.—which compete with other behavior.) This general suppressant effect may clearly be seen in the present data by comparison of the lever extinction outputs of the control groups in Exps. I and II.

Merely giving experimental and control Ss an equivalent amount of shock, however, is insufficient to equate the behavioral effects of environmental stimuli, since experimental Ss also received magazine stimuli as a signal for shock. It is to be expected both on theoretical (6) and experimental (8) grounds that a warning signal prior to an aversive stimulus should decrease aversive conditioning of the environmental stimuli, since the latter then form only a part of the total secondary aversive compound. This effect may be called, in a purely descriptive sense, the "buffer" effect. For present purposes, the buffer effect implies that magazine stimuli preceding shock should decrease the subsequent suppression of lever responding by environmental stimuli. For this reason, two control groups were run, one (C_1) receiving a warning tone before shock, and the other (C_2) receiving none. It was felt that Group C_1 should be most comparable to Group E for the behavioral influences of environmental stimuli, while Group C_2 would check the importance of the warning signal. While the difference between C_1 and C_2 in Fig. 3 does not quite attain statistical significance, Fig. 4 reveals that with high likelihood, a warning signal before shock does tend to lessen the aversive conditioning of environmental stimuli.

The possibility must also be considered, however, that tone might have been more effective than magazine stimuli as a buffer, and hence have produced a lever extinction superiority of Group C_1 over Group E apart from any secondary extinction effects. There are, unfortunately, no experimental data on the determinants of buffer efficiency. For present purposes, an attempt was made to evaluate relative "anxiety"

during lever extinction by consideration of defecation rates. The somewhat involved analysis (11) points to an "anxiety" ordering of $C_1 < E < C_2$, with Group C_2 the most disturbed as predicted, but with Group E as close or closer to Group C_2 than to Group C_1 . Presuming an approximately linear relationship between degree of "anxiety" and response suppression over the range concerned, this finding suggests that at least half the observed difference between Groups C_1 and E, already of questionable significance, may be due to emotional differences. It must therefore be concluded that, although the possibility cannot entirely be ruled out that pairing magazine stimuli with shock might have produced a slight loss of lever-pressing strength, the effect is scarcely detectable, at best of only minor importance in the composition of the habit.

Failure to detect any appreciable effect, moreover, can scarcely be attributed to inadequate reconditioning of magazine stimuli. The differences between Group E and Group C_1 or Group C_2 during magazine extinction are even greater than shown in Fig. 4. The distribution of Group E was markedly skewed, with but three *Ss* (14%) accounting for 42% of the group's total output on the first day. Moreover, a typical *S* in Group E showed a positively accelerated daily cumulative magazine extinction curve, clearly indicating extinction of the secondary aversive properties of the magazine stimuli and subsequent reinstatement of their yet unextinguished positive reinforcement value. In contrast, *Ss* of both control groups gave conventional negatively accelerated extinction curves. Obviously, then, pairings with shock were highly successful in endowing magazine stimuli with aversive properties.

Experiments I and II are in complete agreement that under at least some parameters of learning, an instrumental response, once conditioned, is little if at all affected by subsequent modifications in value of the reinforcers by which it was established. The present data do

not, of course, disprove the existence of secondary extinction. They do, however, indicate the phenomenon to be less evident than might be anticipated on theoretical grounds. That secondary extinction does, in fact, exist outside the laboratory would seem scarcely to be doubted in view of the flexibility of behavior shown by at least the higher primates. But if it is the case that an effect so potentially important in the behavioral economy of the organism is this dependent upon the particular parameters of the learning situation, then investigation of the identity and functioning of such parameters becomes of considerable importance to experimental behavioristics. And if further research still fails to reveal secondary extinction, it may be necessary to revise radically some of our expectancies about the constitution of behavior.

SUMMARY

An attempt was made to discover secondary extinction in thirst-motivated lever pressing of the albino rat. A water-reinforced lever habit was established in thirsty rats, with stimuli accompanying water delivery (magazine stimuli) mediating reinforcement of the habit. The effect on the lever habit of modification in the reinforcement value of magazine stimuli was then determined. Two experiments are reported, one in which simple extinction of magazine stimuli as positive reinforcers was attempted, and another in which magazine stimuli were also aversively conditioned. Neither experiment resulted in any apparent degree of secondary extinction.

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