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Exposure to Discriminative Stimuli in Operant Extinction

John A. Dunning

Western Michigan University

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EXPOSURE TO DISCRIMINATIVE STIMULI IN OPERANT EXTINCTION

by

John A. Dunning

A Thesis
Submitted to the
Faculty of the School of Graduate Studies in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
August, 1970
ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. Douglas Anger of the Department of Psychology for his invaluable assistance in the preparation and completion of this project. Appreciation is also expressed to Dr. Ronald R. Hutchinson and Dr. David O. Lyon for their assistance as members of the thesis committee. Finally, I would like to thank the other students working in the laboratory, with whom it has been possible to exchange animal-running duties.

John A. Dunning
MASTER'S THESIS  M-2446

DUNNING, John Alcott
EXPOSURE TO DISCRIMINATIVE STIMULI IN OPERANT
EXTINCTION.

Western Michigan University, M.A., 1970
Psychology, experimental

University Microfilms, A XEROX Company, Ann Arbor, Michigan
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INTRODUCTION

Most theories of operant extinction attribute the response decline to the nonreinforcement of responses. These theories differ in the aspect of the nonreinforced responses to which they attribute the decline, but most agree that the nonreinforced response is the source of the response decline.

These theories fall into two major categories, the interference theories and the inhibition theories. According to the interference theories the nonreinforcement of responses produces some response that is incompatible with the nonreinforced response. In one example the incompatible response appears, when the nonreinforced response is suppressed by fatigue, and this incompatible response then becomes conditioned to the stimulus situation by contiguity (Guthrie, 1952, p. 61). In another example the incompatible response is first elicited by frustrative nonreward and then maintained by avoidance of the frustrating conditions (Adelman and Maatsch, 1955). A third example, Amsel's (1958, 1962; Amsel and Ward, 1965) frustrative nonreward theory, proposes that an unconditioned "frustration response" is elicited by non-reward responses. A "conditioned response of anticipatory frustration"
is developed by Pavlovian conditioning to the stimuli associated with approach, and then this conditioned frustration response moves "forward in time or backward along the instrumental sequence" (Amsel and Ward, 1965, p. 3) and interferes with the original response. The most developed inhibition theory, that of Hull (1943) proposes that reactive inhibition, a primary negative drive similar to fatigue, is generated by responding and is itself capable of producing response cessation. Non-activity is then reinforced by a decrease of reactive inhibition. Non-activity is considered an inhibitory state and is called conditioned inhibition.

Several other theories concerning extinction, such as the discrimination hypothesis and generalization decrement explanations, point to the role of a discrimination between acquisition and extinction conditions. These theories seem to emphasize the role of certain stimulus changes between reinforcement and extinction, but unreinforced responses still produce the discrimination as well as the response decline in extinction; consequently these theories seem to be adding neglected variables to the above theories rather than replacing them.

The empirical cause, the source of the response decline, seems to be the unreinforced responses in both interference and inhibition theories, as well as other
theories. They seem to start with the unreinforced responses, although they derive the response decline in different ways. But there may be another source of the response decline that has received little attention in the extinction literature. During operant extinction there is considerable exposure to the discriminative stimuli present during conditioning, but these stimuli are no longer paired with reinforcement. This cessation of the pairing of reinforcement with certain stimuli has been largely overlooked, although there are some relevant experiments. Logically both changes, both the cessation of the reinforcement-response pairing and cessation of the reinforcement-stimulus pairing, may contribute to the decline in responding. For example, it might conceivably be possible that a response could be eliminated by suitable manipulation of discriminative stimuli without any further occurrence of the response. This possibility has some similarity to discriminations learned without the occurrence of responses to the nonreinforced stimulus (Terrace, 1963), although other mechanisms may be involved in the latter. This possible effect of discriminative-stimulus exposure on operant extinction will be referred to here as the stimulus-effect.

Moderate consideration has been given to the possibility of stimulus exposure in Pavlovian extinction.
Guthrie (1935) proposed that a response could be reduced by a "toleration" method, in which the conditioned stimulus is gradually introduced but kept too weak to produce the conditioned response. Sheffield (1949) proposed that the effectiveness of this technique might be a critical test of the theories of Guthrie and Hull, as the latter cannot predict fewer responses in extinction with a "toleration" technique. One experiment has been reported in which stimulus exposure was manipulated in the extinction of signaled avoidance behavior to explore Guthrie's "toleration" technique (Kimble and Kendall, 1953). In a stimulus-exposure extinction group each trial began with a dim warning light which gradually increased to training intensity during the trial providing no response occurred. The onset brightness of the warning light was also increased from trial to trial until training intensity was reached. An ordinary extinction group received the warning stimulus at full intensity throughout. Animals receiving stimulus-exposure extinction made significantly fewer responses.

The Kimble and Kendall experiment seems to show the role of stimulus exposure in Pavlovian extinction. The best interpretation of avoidance behavior seems to be that the warning stimulus is made aversive by pairing it with shock, and the termination of the warning stimulus after the avoidance response provides
reinforcement for that response. To the extent that this interpretation is correct, Kimble and Kendall extinguished the conditioned aversiveness of the warning stimulus, extinction of Pavlovian conditioning, by exposure of the animal to it in such a way that it did not produce the avoidance response.

The extensive literature on habituation supports the possibility of a stimulus-effect. Habituation is the most widely used term for response decrement produced by repeated stimulation when the decrement is neither a result of receptor adaptation nor a result of effector fatigue. The term usually is used for unconditioned responses to unconditioned stimuli, although it has been proposed that habituation and extinction are the same process (e.g. Pavlov, 1927; Razran, 1930; Humphrey, 1930; Thompson and Spencer, 1966). Thompson and Spencer cite such similarities as spontaneous recovery, dishabituation, acceleration by massing, and "below-zero" effects. Examination of these claims indicates, however, that these proposals of equivalence between habituation and extinction seem to be considering Pavlovian, rather than operant, extinction.

Stimulus exposure does seem to play a role in many cases of habituation, though not all (Hinde, 1966, p.209). Habituation is often specific to the stimulus or modality
employed, sometimes remarkably specific (Hinde, 1966, pp. 205-209). After complete habituation of a response to one stimulus a very slightly different stimulus can sometimes still produce the response. Little or no habituation occurs with high stimulus intensities (Thompson and Spencer, 1966, p. 19) even though the response may become completely habituated to a weaker stimulus (Hinde, 1966, pp. 209-210). Continued exposure without the occurrence of an overt response may increase habituation (as measured by a delay of recovery) both in habituation "below-zero" (Humphrey, 1933) and in habituation of the EEG arousal response (Sharpless and Jasper, 1956; see Thompson and Spencer, 1966).

A good case has been made that one type of operant responding is depressed by discriminative-stimulus exposure. Spontaneous alternation, the tendency to alternate between two equal-reinforcement responses, has been ascribed to "stimulus satiation" by Glanzer (1953), who reviews considerable data that indicate the reduction of responding is related to stimulus exposure rather than to the occurrence of responses. Thompson and Spencer (1966, p. 31) point out that stimulus satiation apparently has the same properties as habituation.

Results from two other studies support a stimulus-
effect (Brown and Bass, 1958; Bacon and Bindra, 1965). Both these studies examined the effect of stimulus variation during conditioning and extinction of alley running. In both experiments some rats were trained in just one alley and other rats in several alleys, and then subgroups were given either single- or multiple-alley extinction. Brown and Bass used three different alleys, with three different start and goal boxes; Bacon and Bindra varied only the start boxes. In both studies the group extinguished with varied stimuli showed significantly slower extinction, as measured by slower increases in both starting and running times, than did the group without stimulus changes in extinction. This difference occurred independently of whether the alleys were constant or varied during training. These results fit a stimulus-exposure analysis nicely since the stimulus variation would be expected to attenuate the stimulus-exposure effect and hence slow extinction.

Brown and Bass concluded that their results might be due to "a joint effect of disinhibition and stimulus satiation" (1958, p. 503). Part of that interpretation agrees with the stimulus-effect interpretation, since stimulus satiation, Glanzer's term (1953), seems to be close, if not equivalent, to habituation (Thompson and Spencer, 1966) and the stimulus-effect. Let us delay
consideration of the possible role of disinhibition until after consideration of Bacon and Bindra's conclusions. They conclude: "This effect is attributable to some general energizing or disinhibiting influence of stimulus variation on response tendency and is not a specific stimulus satiation effect." (1965, p. 119). They seem to assume that their variation of only the start box stimuli would decrease stimulus satiation only in the start box, and not affect running times beyond the start box, whereas a disinhibition effect of varied stimuli would appear in both starting and running times. Consequently they rejected stimulus satiation because both response measures were affected the same by start box variation. But their rejection does not seem justified because the start box stimuli may well influence the behavior in the alley as well as in the start box.

Responding frequently comes under the stimulus control of preceding events, such as time since last reinforcement (Ferster and Skinner, 1957), or last response (Anger, 1963), or presence-absence of food at some prior point (Tyler, Marx, and Collier, 1959).

Furthermore, the data available on disinhibition indicate that it is inadequate to explain the results in these two studies. Except possibly with painful stimuli (electric shock), disinhibition of operant
responses has proved hard to demonstrate with any consistency (Skinner, 1936; Horns and Heron, 1940; Yamaguchi and Ladioray, 1962). When disinhibition has been found, the effect has fallen off quickly with repetition of the disinhibiting stimulus (Wenger, 1939: 36% and 64% decreases for two different groups from the first to fourth presentations; Switzer, 1933: 61% decrease from the first to fourth presentations; see also Pavlov, 1927). More detailed studies of dishabituation have also shown a rapid decline with repetition (e.g. Lehner, 1941, found that the average number of presentations for which a dishabituating stimulus was effective was 3, 3 and 5 with three different responses).

The Bacon and Bindra results are in sharp contrast to the data on disinhibition and dishabituation, since their group with varied start boxes in both training and extinction already had 60 trials with the four different start boxes before the start of extinction, and yet the behavior of this group was no different than the behavior of the group which first encountered new start-boxes in extinction. The persistence of the Bacon and Bindra effect, and the lack of an effect when stimulus variation was first begun, do not fit the disinhibition explanation. Thus, these two experiments seem to support the stimulus-exposure viewpoint, although the reduction of stimulus exposure is complicated by the
introduction of new stimuli and hence other interpretations are possible.

Certain other experiments seem at first to be relevant to the present problem but turn out to be quite different upon closer examination. Latent extinction, in which nonreinforced exposure is given to goalbox stimuli or to stimuli associated with food delivery (e.g. Seward and Levy, 1949; Moltz and Maddi, 1956; Coate, 1956; review by Moltz, 1957) is the effect upon a response of exposure to stimuli at the end of a sequence of behavior. The stimulus-effect, however, refers to exposure to discriminative stimuli that precede the response, a different procedure. The latent extinction experiments have been construed as supporting the general idea of a response-effect, whether analyzed in terms of anticipatory goal and frustration reactions (e.g. Moltz, 1957; Clifford, 1954) or in terms of response chains (e.g. Coate, 1956; Ratner, 1956).

The experiments on blocking or breaking of an operant response chain short of the terminal member also seem at first to be relevant, but they too are concerned with the stimuli following the extinction response. Either the placing of a barrier in an alley (e.g. Williams and Williams, 1943; Lambert and Solomon, 1952) or the elimination of secondary reinforcers associated with food delivery (e.g. Bugelski, 1938; Bersh, 1951;
Miles, 1956) is a manipulation of conditioned reinforcing stimuli late in the chain. These experiments differ from latent extinction in that the extinction responses are reduced by less, rather than more, exposure to the stimuli late in the chain.

In summary the possible effects of discriminative-stimulus exposure in operant extinction have barely been mentioned in the literature and have not been elaborated. There is, however, scattered evidence in the literature that a stimulus-effect might play a role in operant extinction, although little evidence comes directly from operant extinction procedures. The evidence of an important response-effect is not in question, the possibility being raised is that there is a stimulus-effect in addition. Considerable search has revealed no direct experimental study of the role of stimulus exposure in operant extinction by increasing the exposure to the discriminative stimuli controlling the response. The present experiment attempts such a direct test.

In extinction responses ordinarily occur along with exposure to the discriminative stimuli (S+) that control the responding, so the stimulus-effect and the response-effect usually occur simultaneously. The objective of this experiment was to separate these two effects to some extent by increasing the stimulus-effect and
reducing the response-effect. Success in this attempt is seen as fewer responses in extinction. Increase in the stimulus-effect was attempted by starting extinction with completely dark house and key lights, after which a key stimulus to which the animal would not respond (S-) illuminated the key once a minute for 40 sec. This stimulus was gradually increased in intensity, and then the stimulus to which the animal previously did respond (S+) was introduced and gradually brightened during the 20 sec. period between each S-. If exposure to a discriminative stimulus (independently of responding) does lower the response probability to that stimulus and to closely related stimuli, then during the slow introduction of S- and S+ the animal will never receive a stimulus without being first exposed to a closely similar stimulus for a long time. Hence a low probability of responding may be achieved to all stimuli to which the animal is exposed, including eventually S+.

Production by the fade-in procedure of the same low probability of response to S+, but with fewer responses than the usual extinction procedure, would indicate an effect of discriminative-stimulus exposure.

This experiment requires that the experimenter have a high degree of control over the discriminative stimuli controlling the response. For this reason a discrimination between two different key colors was established.
during the reinforcement phase that preceded extinction.
METHOD

The following features were common to all the experiments.

Subjects

Experimentally naive female White-King retired breeders (Palmetto Pigeon Plant) were maintained at approximately 70% of ad libitum weight by feeding them a constant amount of Purina "Pigeon Grains" each day. A slight feeding adjustment was made only if a consistent trend in weight occurred. Birds were housed in individual cages with grit and water available except during the experimental session and for two hours thereafter. The two hours after the session were spent in a cage like the home cage and were followed by return to the home cage and feeding.

Apparatus

Two different experimental chambers were used. Chamber A was a converted picnic box containing a single Gerbrands pecking key. The key had a diameter of 3/4 in., was mounted 5/16 in. behind the panel, and required a displacement of 1/64 in. to operate the circuit. This key was illuminated from behind by either a white or green Christmas-tree bulb. The houselight was a 6-watt
bulb mounted on the ceiling and shielded to prevent direct illumination of the key. This bulb was rated at 120 volts but only supplied with 50 VAC. A series of autotransformers and meters allowed independent brightness control of each bulb.

Chamber B was a standard Lehigh-Valley-Electronics 2-key chamber except the houselight was changed to a 120-volt, 6-watt bulb. Each key had a diameter of 1 in., was mounted 3/16 in. behind the panel and required a displacement of 3/64 in. to operate the circuit. Only pecks on the right key had any effect. The right key was illuminated by a projector (Industrial Electronics Engineers, Inc., Series 10). The green stimulus resulted from 25 VDC on a GE 1820 bulb behind a green filter. The white stimulus resulted from 25 VDC on a GE 756 bulb with no filter. Stimulus intensity was manipulated by potentiometers, houselight intensity by an autotransformer ordinarily supplying 115 VAC.

Both chambers were located in a room which was separated from the electromechanical programing and recording equipment by a hall.

Key-peck Training

All birds were trained to key-peck by an adaptation of the auto-shaping procedure of Brown and Jenkins (1968). Seven-second presentations of a white key-light,
immediately followed by 3 sec. of food access, were given on a variable interval (VI) schedule. For this white key-light 80 VAC were used in chamber A, 25 VDC in Chamber B. A peck to the white key-light immediately terminated it and produced food access, while a peck to the dark key had no consequence. After the fourth peck to a white key-light and the resulting feeding the white key-light came on again and stayed on during 10 continuous reinforcements (CRF), after which the session terminated. Unless 4 pecks occurred by the 51st key-light the session was terminated and another auto-shaping session given the following day. One to three auto-shaping sessions were generally required, and no more than four were used.
In order to demonstrate any fade-in effect there must be ordinary extinction data for comparison. With repeated extinction the two procedures can be compared within the same animal, and the effect of individual differences thus reduced, but extinction is not reversible and responses decline on successive extinctions. A simpler comparison might be between two random groups of subjects. This preliminary experiment explored the feasibility of this approach.

Procedure

Chamber B was used with no resistance in series with either stimulus bulb.

Four pigeons were run in pairs (one ordinary and one fade-in extinction per pair) and a fifth bird was given fade-in extinction. All birds received 4-hour sessions of VI 4-min. with S- introduced at the start of the second day. Twenty-second periods of white (S+) and forty-second periods of green alternated with no intervening dark period. The first pair received 5 days of training (Treatment 1 in Table 1) while the other 3 birds received only 4 days (Treatment 2 in Table 1).
The fade-in procedure began with full chamber illumination and a dark key. Steady illumination on the key was slowly increased to the training brightness of green (S-) and then slowly changed to white (S+). Then to the constant white was added a 20 millisecond flash of green every 20 seconds. This flash was gradually increased to 40 seconds, the training duration of S-. The fade-in procedure was completed in 6 to 27 days.

Results and Discussion

The results are presented in Table 1. Although the fade-in extinction responses of each pair were fewer than the ordinary extinction responses, the differences in treatment between pairs did not seem sufficient to account for the huge differences between groups. Furthermore, the two fade-in birds with the same training differed by a factor of ninefold.

An attempt was made to find some factor in the acquisition data of these birds that would predict individual differences in extinction (e.g. response rate in S+ or rate of decline of S- responses). No measures were found using these data with a sufficient correlation for such a prediction, and no indication was found in published reports that such a prediction was possible.

The inability to predict extinction responses when such inter-subject variability was encountered seemed
too great an obstacle, so this approach was abandoned.
Table 1. Preliminary Experiment I: extinction responses in ordinary and fade-in extinction for 5 birds given two slightly different training treatments (see text).
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ordinary</th>
<th>Fade-in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment 1</td>
<td>3006</td>
<td>1207</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>686</td>
<td>512</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4651</td>
</tr>
</tbody>
</table>
PRELIMINARY EXPERIMENT II

The excessive variability encountered in Preliminary Experiment I led to reconsideration of a repeated extinction design. Survey of the literature indicated that the decline between just the first and second extinction is not particularly large following intermittent appetitive reinforcement (See Table 2). Data were analyzed from the three published reports with such reinforcement and representing different schedules. The mean decrease from first to second extinction was 18%, with a range of 8-44%. These data indicate that the fade-in and ordinary extinction might be compared in the same bird. The decrease from first to second extinction might be less of an obstacle than the animal variability found in the group comparison technique of Preliminary Experiment I. With a small decrease between extinctions the fade-in extinction could be first and the ordinary extinction second, and the decline would oppose results supporting the stimulus-exposure view but would not be too serious an obstacle to overcome.

Procedure

One bird was given two ordinary extinctions with a brief reconditioning in between. Chamber B was used with no resistance in series with either stimulus bulb.
On the session after key-peck training both variable-interval and discrimination training were begun. Two CRF were given, followed by 8 reinforcements on VI 30-sec. Twenty seconds after the tenth reinforcement on white the key became green (S-) for 40 sec., and subsequently 40-sec. periods of S- and 20-sec. periods of S+ (white) alternated with no intervening dark period. After 5 more reinforcements the VI was changed to the final 1-min. schedule. Sessions lasted 2 hours. This procedure reliably generated responding with few pauses over 20 sec. After a second day of VI 1-min., ordinary extinction was given with a criterion of 4 consecutive days with 5 or fewer responses. Then a second extinction to the same criterion followed 2 more sessions of VI 1-min. Only 2 CRF preceded the return to VI 1-min.

Results and Discussion

On the first extinction the bird required 8 days to reach the criterion and made 653 responses. On the second extinction the bird made only 130 responses, a decrease of 80%. The first extinction lasted 16 hours, 8 sessions, while the extinctions reported in Table 2 were all for one hour or less in a single session. Consequently the most likely explanation for the difference between these results and those in the literature seems to be the duration of the first extinction.
Table 2. Percent decrease from 1st to 2nd extinction as a function of reinforcement schedule. All percentages were estimated from graphs presented in the published reports.
<table>
<thead>
<tr>
<th>Schedule</th>
<th>Percent Decrease from 1st to 2nd Extinction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perkins and Cacioppo (1950): VR 2</td>
<td>18</td>
</tr>
<tr>
<td>Bullock (1960): FR 10</td>
<td>44</td>
</tr>
<tr>
<td>FI 26-sec.</td>
<td>10</td>
</tr>
<tr>
<td>Clark (1964): VI 1-min.</td>
<td>11</td>
</tr>
<tr>
<td>VI 1-min.</td>
<td>8</td>
</tr>
<tr>
<td>Mean</td>
<td>18</td>
</tr>
</tbody>
</table>
The decrease in responses between the two ordinary extinctions made the comparison of fade-in and ordinary extinction in the same animal appear impractical. A small decrease could perhaps be neglected, and different types of extinction could be compared successively if orders were counterbalanced or if control groups showed the nature of the change between extinctions of the same type. But a change of 5 to 1 between the first and second extinctions means a major difference in the conditions of the two extinctions. It seemed most unwise to try to compare fade-in and ordinary extinction in the presence of such variation from another source, itself poorly understood. Whatever the source of this 5 to 1 difference, variation in this difference would be expected to contribute considerable additional variability to the comparison and the difference might not be the same after fade-in and ordinary extinction.
EXPERIMENT III

In view of the difficulty encountered in both group and within-subject comparisons a compromise technique was tried in Experiment III. All birds received ordinary extinction for one day in an attempt to assess individual differences. Then after reconditioning one group of birds received ordinary extinction and another group received fade-in extinction. It was hoped that the first one-day extinction would not lower the second-extinction responses seriously. It was also hoped that the effect of subject variability on the group comparison might be reduced by comparing fade-in and ordinary birds with similar first-extinction responses. Such a comparison would examine whether the curve for ordinary second extinction lies above the curve for fade-in second extinction when both are plotted against first-extinction responses.

Procedure

Birds were run in both chambers. In chamber A the training voltages on white (S+) and green (S-) were 23 and 43 volts respectively. In chamber B, 310 and 280 ohms, respectively, were put in series with a 25 VDC power supply. The settings were chosen to make all four stimuli appear equally bright to human observers with
both houselights set at 115 volts. The houselight voltage of chamber A was then changed to 50 for all training, while the chamber B voltage remained at 115. The result of this matching procedure was that the stimuli in chamber A were bright colors relative to the surround, while the key in chamber B remained darker than the surround, and thus less easily discriminable.

Initial training was identical to that in Preliminary Experiment II. After 2 CRF and 8 VI 30-sec. reinforcements with the key white, the stimulus cycle of 40-sec. green (S-) and 20-sec. white (S+) began. After 5 additional reinforcements the VI changed to the final 1-min. schedule. Sessions lasted 2 hours. After a second day of VI 1-min. a single day of ordinary extinction (the only change from training being absence of reinforcement) was given, followed by two more days of VI 1-min. Finally each bird received either ordinary or fade-in extinction to a criterion of 5 (chamber A) or 4 (chamber B) days with 5 or fewer responses.

The fade-in extinction procedure began with both house and key lights off; their intensity was subsequently increased, houselight first, S- next, and then S+. Only after one stimulus reached the brightness used in training (training voltage) was increase of the next begun. From 20 to 26 days were required to advance all these starting voltages from zero to training voltage in
chamber A, and from 26 to 37 days in chamber B.

In chamber A stimulus increments ranged from 20 volts at low voltages of the houselight to 1/2 volt near the training voltage of S+. In Preliminary Experiment I it was learned that relatively rapid changes could be made until S+ approached the training voltage. Consequently changes were rapid at first, and by the fourth or fifth day birds started the session with the training voltages of houselight and S- and with 15 volts on S+ (training voltage is 23). At this point voltage increments were reduced to 1/2 volt and only one to four were made per day. The starting voltage also increased 1/2 volt per day. Houselight and S- remained at training voltages. Stimulus intensity was never reduced within a session.

The birds tested in chamber B exhibited poorer discriminations and responded more during the early fade-in sessions while the houselight was being increased. Consequently, the houselight was changed more slowly for these birds.

In chamber A the pattern of stimulus change during the fade-in procedure is best described by the starting and ending voltages of each session. After the first few days the starting voltage advanced 1/2 volt per day regardless of the bird's behavior. In some of the first fade-in birds the starting voltage occasionally did not
increase on the day following many responses, but this approach was discarded. The within-session advances, however, were highly dependent on the behavior. Since all birds slept much of the time observation was necessary to determine that a bird had spent some time observing the stimulus without responding before that stimulus was brightened. The procedure was similar in chamber B.

The same extinction criterion used for the ordinary birds applied to the fade-in birds after training voltages were reached.

Earlier studies had encountered a few birds with extremely low extinction responses. Some of these extreme birds appeared in poor health, and one died immediately after an extinction with unusually few responses. Although such birds were infrequent, they greatly complicated group comparisons. The experimental design of this experiment made it practical to objectively eliminate such sick and other extreme birds after the first extinction, and before obtaining any second extinction measurements. Consequently, a minimum of 200 first-extinction responses was set, and one bird with 116 responses was discarded.
Results and Discussion

The results are presented in Figure 1, where the second-extinction responses of each bird are plotted on the ordinate against the first-extinction responses of the same bird on the abscissa. The 13 solid points show the birds with an ordinary second extinction and the ten open points show the birds with fade-in second extinction. The circles, solid and open, indicate the birds that were tested in chamber A while the squares, solid and open, indicate the birds that were tested in chamber B. The difference between the results from the two chambers is remarkably small in view of the variability between birds. Consequently the results are pooled and the chamber differences ignored hereafter.

If we ignore the measurement of the first-extinction responses and just compare the second-extinction responses, the fade-in extinction responses with a mean of 886 are less than the ordinary extinction responses with a mean of 1262. This reduction in extinction responses by fade-in extinction is in the direction predicted by the stimulus-effect. The difference between the two groups was significant at the .025 level by the Mann-Whitney U test (one-tailed).

However, the purpose of the first-extinction measurement was to estimate bird differences and to use that
Figure 1. Responses to criterion in second extinction as a function of responses in first extinction (one day ordinary in all cases). Solid circles and squares indicate ordinary extinction and open circles and squares indicate fade-in extinction. Circles are birds tested in chamber A and squares are birds tested in chamber B.
measure, if possible, to compare fade-in and ordinary extinction in more comparable birds. Examination of Figure 1 indicates that the first- and second-extinction responses are related. The product-moment correlation coefficient between the first-extinction responses and all second-extinction data was .60 (n=23, significant at the .01 level). The birds with an ordinary second extinction had a coefficient of .53 (n=13, not significant); the birds with a fade-in second extinction had a coefficient of .74 (n=10, significant at the .05 level).

Thus birds with low first-extinction responses responded less on the second extinction than birds with high first-extinction responses. Consequently there is reason to consider separate comparisons of fade-in and ordinary extinction in birds with high and low first-extinction responses. Examination of this question in Figure 1 shows that birds with over 700 first-extinction responses (the high half of the range) show no evidence of a difference between the fade-in and ordinary extinction. The mean fade-in responses was 1881, almost identical with the mean ordinary responses of 1699. However, it should be noted that only 7 of the 23 birds in the study fell in this region.

The significant overall difference between fade-in and ordinary extinction responses is due to the big
difference between fade-in and ordinary extinction responses in the other 16 birds with fewer than 700 first-extinction responses. Here the means are 512 and 1068, a reduction of extinction responses to one-half by fade-in extinction. This difference was significant at the .01 level (Mann-Whitney U test, one-tailed). The exact point of separation between the high and low groups is unimportant in this comparison; for example, a comparison of birds with fewer than 550 first-extinction responses showed a significant difference at the same level.

Thus the big sample of birds with low first-extinction responses seems to be different from the smaller sample of birds with high first-extinction responses, both in the average second-extinction responses and in the effect of fade-in extinction. The evidence seems good that fade-in extinction reduces extinction responses in birds with low first-extinction responses, but there is no evidence of such an effect in birds with high first-extinction responses. This lack of evidence might be due to the small sample of birds with high first-extinction responses, and more measurements are necessary to clarify this question. However, the equality of fade-in and ordinary extinction responses in the present sample does not encourage the expectation that a difference will appear on further testing.
Although unexpected there seems to be no lack of explanations why fade-in extinction should be less effective in birds with high first-extinction responses. Two possible explanations are the following: (1) When a bird has high first-extinction responses that may indicate more effective conditioning. Probably with stronger conditioning it will be more difficult to make the fade-in procedure effective. (2) When a bird has high first-extinction responses it may indicate that whatever processes reduce the responding in extinction are less effective in that bird. Thus the stimulus-effect may be less effective in these birds, in which case it would be expected that fade-in extinction would be less effective.

At least one control experiment would be desirable in addition to the basic comparison of fade-in and ordinary extinction in order to eliminate alternative explanations of the lowering of extinction responses by fade-in extinction, but such a control experiment is beyond the scope of the present study. The possibility of alternative explanations arises from the different time requirements of fade-in and ordinary extinction. Since both extinctions are carried to a response criterion they will be of different durations. In this experiment the mean duration of extinction was 14 days for the ordinary group and 36 days for the fade-in group.
The longer duration of fade-in extinction would provide more opportunity for the animal to respond, which would tend to produce more extinction responses, and would oppose the obtained effect. No alternative explanation for positive results arises in this way. Nor does the greater duration of stimulus exposure during fade-in extinction pose a problem, because the effect of increased stimulus exposure is the effect we wish to demonstrate.

There does seem to be one effect that could be confounded with stimulus exposure. The fade-in procedure is designed to minimize responding over a period of 3-5 weeks while the discriminative stimuli are gradually introduced, and it might be argued that forgetting takes place during that time. The available literature, however, indicates that forgetting is minimal over periods as great as four years (Skinner, 1938, 1950; Hoffman, Fleshler, and Jensen, 1963; Hoffman, Selekman, and Fleshler, 1966). It seems unlikely that the significant difference found in the present study could be accounted for by such a weak effect.

There are some reasons for expecting that the response-effect might be more important early in extinction and the stimulus-effect might be more important late in extinction. In the long ordinary extinctions (the second ones) of Experiment III an average of 78% of the responses
occurred on the first day, while the remaining responses were spread over many days of extinction. Thus the density of unreinforced responses was much greater early in extinction. But this high density of unreinforced responses, which probably is a major source of the response-effect, is very brief, and the response-effect may diminish on days when few or no responses occur. A decline in the response-effect seems especially likely if concentrations of nonreinforced responses produce some sort of aversive stimulus which plays an important role either directly or via the formation of conditioned aversive stimuli. Then late in extinction the lack of aversive stimuli may lead to a decline in the response-effect. Thus the response-effect is probably maximally effective early in extinction and might decline in effectiveness during extinction, though whether such a decline is major or minor is unknown.

On the other hand, discriminative-stimulus exposure without food continues unchanged throughout extinction, and may even be cumulative, so the stimulus-effect may be weak at the start of extinction and grow more effective as extinction proceeds. Thus the stimulus-effect may have the properties to control responding late in extinction due to its growth and either the stabilization or weakening of the response-effect.

The data from birds with two ordinary extinctions in
Experiment III were used to explore this possible change of control. Throughout this discussion, the term "strength of stimulus-effect" will be used to refer to consistent differences between birds in their stimulus effect, in the ability of stimulus exposure to depress responding, and "strength of response-effect" will similarly be used for bird variation in the effectiveness of the response-effect. It seems possible that the strength of the stimulus- and response-effects may vary independently in different birds. If they do vary independently it may be possible to use these fluctuations between birds in the strengths of the two effects to determine their relative role in different parts of extinction. If the same effect controls the responding in different extinctions or in different parts of the same extinction the correlation between the responses of the various birds on those extinctions or parts of extinctions should be high. On the other hand, if the two extinctions or parts of extinctions are controlled by different effects the correlation should be low. For example, if both first- and second-day responding are controlled by the response-effect the correlation between responses on those two days should be high, whereas that correlation should be low if responses on one or the other day are controlled by the stimulus-effect. Thus bird fluctuations may provide a tool for determining what
parts of what extinctions are controlled by the same effect and what parts by different effects.

The responses on the first day of extinction have been used as one measure, because it is a convenient measure of the initial high rate of extinction responses. Hopefully it is more sensitive to the response-effect due to the high response rate and high number of responses (mean 78%) on the first day. The relation of this measure to other measures was studied in the data from the birds with two ordinary extinctions. The responses on the first day do correlate between the first and second extinctions in the same birds (r=.61, significant at .05 level—All correlations presented here are product-moment correlations). This correlation probably indicates persisting bird differences. The number of days required to meet a severe extinction criterion seems to be the most promising measure for late extinction responding, and hopefully for the stimulus-effect. Such a measure has two advantages; it seems to be minimally affected by the high responding in the early days of extinction, and it does not necessitate an arbitrary cut-off point between early and late responding. In the second extinction, the only one in which it was possible to take this measure, the days to criterion showed little correlation with responses on the first day (r=.01). This low correlation seems to indicate that whatever reduces the
low rate of responding late in extinction is different from whatever reduces the initial high rate of responding. However, the days to criterion measure might represent chance fluctuation unrelated to any other measure. Since these birds had only one long extinction, the correlation between corresponding measures of two extinctions cannot be determined. Consequently, other measures of the responding after the first day of extinction were examined to determine their correlation with both the first-day responding and the days to criterion.

Responses on the second day of extinction are correlated with responses on the first day ($r = .76$, significant at .01 level), indicating that the effect controlling the first-day responses persisted into the second day. Examination of extinction responses over days indicated that for some birds this relation seemed to persist into the third and fourth days too. Responding after the fourth day was highly correlated with the days to criterion ($r = .93$, significant at .01 level) but apparently not very highly with responses on the first day ($r = .10$). Even responses on days 5 through 8 correlated with days to criterion ($r = .79$, significant at .01 level) and with responses after the eighth day ($r = .81$, significant at .01 level), but did not correlate very well with first-day responses ($r = .44$). The high correlation between responding on different days late in
extinction and their correlation with days to criterion indicated that the behavior was consistent during the later days of extinction. Thus the relatively low correlation of late responding with first-day responding was not due just to chance fluctuations in late responding but instead might be due to a consistent difference between birds in some other variable besides the one which controlled early extinction responding.

The differences between birds in early and late extinction responses may be due to differences in the strengths of the response- and stimulus-effects, respectively, since many responses occur early in extinction and much stimulus exposure with few responses occurs later in extinction. Thus these correlations provide further support for the analysis in terms of stimulus- and response-effects. However, the finding that birds vary independently along two dimensions, early and late extinction responding, stands on empirical evidence; it is not necessary that these two dimensions be the response-effect and stimulus-effect as described in this paper.
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