RESISTANCE-TO-EXTINCTION FUNCTIONS IN THE SINGLE ORGANISM

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Functions relating the number of reinforcements to some aspect of behavior are most often obtained through the use of different groups of subjects, each given different numbers of reinforcements before a test phase that is the same for all groups. The average of the individual measurements in each group then is related to the number of reinforcements given each group. By such a method, the classic data of Williams (1938) and Perin (1942) have shown that both the mean number of extinction responses and the mean time required to attain an "extinction criterion" increase with negative acceleration as the number of reinforcements increases. Williams and Perin plotted the individual data points which enter the mean of each of their reinforcement groups. It is noteworthy that in Williams' experiment, (a) the two highest individual scorers in extinction were members of one of the low-reinforcement groups; and (b) the range of extinction scores in three of the four experimental groups was virtually the same, even though the group mean scores revealed an orderly and significant relation with the number of reinforcements. In Perin's study, all five reinforcement groups displayed their modal number of individual extinction responses at zero, although the mean data indicated a relation very similar to that of Williams.

Some recent papers have considered the problem of drawing inferences about individual behavioral functions from group data (Sidman, 1952; Estes, 1956; Schrier, 1958), and there has been some consideration (Spence, 1956; Skinner, 1959) of the relative merits of individual and group functions in behavioral research. In view of these discussions and of the individual eccentricities pointed out in Williams' and Perin's data, the present set of experiments was undertaken (a) to examine a technique for obtaining resistance-to-extinction functions in individual subjects, and (b) to compare these findings with results previously obtained by separate-group methods. The present technique is founded on the pigeon's capacity for very efficient and rapid color discriminations (Ferster & Skinner, 1957) and on an extinction testing procedure analogous to that used by Guttman and Kalish (1956) and Hanson (1959) in the study of individual and small-group generalization gradients in the pigeon.

EXPERIMENT I: METHOD

Subjects

The Ss were eight barren, White Carneaux hen pigeons, ranging from 4 to 8 years old. Throughout the experiment, they were maintained at 75% of their free-feeding body weights.

Apparatus

The experimental box was a standard commercial model (Foringer), and its essential details have been described elsewhere (Ferster, 1953; Ferster & Skinner, 1957). Except during blackout periods (described below), the box was illuminated by a 110-volt-AC, 6-watt houselight mounted inside the electrical junction box on the rear wall of the chamber.

The translucent response key could be illuminated with four pairs of colored Xmas tree lamps (red, green, blue, or orange) mounted behind the key. These lamps were 110 volts, 7.5 watts, which effectively prevented stimulus flicker and provided adequate illumination.

Appropriate control and tabulation of key-pecking behavior, reinforcements, stimulus presentations, etc., were accomplished automatically through the use of a system of relays, timers, and counters.

Procedure

After subjects had stabilized at their 75% running weights, they were on several occasions given punchboard training (Ferster & Skinner, 1957, p. 32) in their living cages. Such preliminary training was carried out so that the subjects would be more likely to peck at the response key when later placed in the experimental chamber. All subjects learned to peck at the punchboard on the first or second day of its availability.

A week after punchboard training, each subject was placed in the illuminated experimental chamber for 20 minutes on 2 successive days, with the response key covered over with black tape so as to make it inaccessible to the subjects. These adaptation periods were designed to acclimatize the pigeons to being transported into and out of the experimental box, etc. For several days following these sessions, birds were given magazine training in the illuminated box. The key remained inaccessible to the bird, as it had been during the preceding adaptation phase.

Following adaptation and magazine training, birds were placed in the experimental box for a single short session during which the response key, dotted with several pieces of grain and not illuminated or colored, was made available for the first time; 5 or 6 pecks at the key were rewarded by the presentation of the grain magazine for 4 seconds per reinforcement. This phase of the experiment, in addition to the punchboard training mentioned earlier, was included in order to raise the likelihood of pecks at the well-illuminated colored key used in the subsequent conditioning and extinction phases. Williams (1938) and Perin (1942) similarly tried to speed up the conditioning procedure (and thus better equalize the amount of time spent by each subject in the conditioning situation) by smearing the lever with wet mash.

Conditioning. For 3 successive days, each bird then was exposed to the following conditioning procedure. Forty-eight conditioning trials were run each day. A trial consisted of (1) the illumination of the response key with one of the four possible key colors; (2) a pigeon's peck at this colored key; and (3) the immediate activation of the grain magazine as reinforcement for the key peck. Each reinforcement was followed by a 15-second blackout (or intertrial interval), when all cage and key illumination was shut off. Then, the cage light was again turned on and the key illuminated until a peck occurred, reinforcement followed, etc. By this method, subjects were regularly reinforced, i.e., rewarded for every response that occurred on the illuminated key. All subjects made virtually zero keypecks in blackout periods.

The number-of-reinforcements variable was manipulated by presenting the four key colors different numbers of times in each session. Out of the 48 daily trials, one color appeared 2 times, another 6 times, another 14 times, and the other 26 times. During the three conditioning sessions, key pecks at the four different colors received a total of 6, 18, 42, and 78 reinforcements, respectively.

Since color preferences by the subjects might have influenced the results, different colors were associated with different numbers of reinforcements in different birds. Half the subjects were rewarded 6 times on the red, 18 times on the green, 42 times on the blue, and 78 times on the orange stimulus; the other four subjects were rewarded 6 times on the blue, 18 times on the orange, 42 times on the green, and 78 times on the red. These correlations

between color and number of reinforcements were prearranged to control partially for effects which might result from individual generalization gradients. For example, if red were rewarded 78 times, the color closest on the visual spectrum (here orange) was not the next most frequently reinforced, etc.

The different colors were presented in a mixed order during each conditioning session of 48 trials. Different color sequences were programmed for each subject on each of the three conditioning days, so that the first or last color presented during experimental sessions was not always the same one, etc.

Extinction. Each subject was run for two extinction sessions. One of these followed the final conditioning period by approximately 3 hours, and the other occurred on the following day, approximately 20 hours later. During each extinction session, the four colors were presented equally often (20 times each) for a total of 40 presentations per color over the two extinction periods. Each key color remained on for 15 seconds, whether or not the subject pecked at it; 15-second blackouts occurred between color presentations. The order of presentation of the different colors was random. Different orders were used for different subjects, and each subject was exposed to a different sequence on the second day of extinction than on the first.

Total number of responses per stimulus, latencies of the first response to each stimulus presentation, and the probabilities of at least one response per presentation of each stimulus were tabulated for each subject during these extinction tests.

EXPERIMENT I: RESULTS

Figure 1 shows resistance-to-extinction data for three different response measures. These data represent group results for all eight subjects combined. It must be noted, however, that the grouping procedure of the present experiment differs from that of Williams and Perin in that each individual subject was here exposed to all four values of the independent variable.

The upper panel of Fig. 1 indicates that as the number of conditioning reinforcements increases, resistance to extinction, as measured by total extinction responses to the respective stimulus, generally increases as well. Responding on the first test day exceeds that on the second day by a factor of three or four, but the general form of the relation is quite similar for both extinction tests. An analysis of variance of the pooled data for both days of extinction revealed significant differences among subjects at the .01 level of confidence ($F_{7,21} = 6.18$) and among number of reinforcements at the .05 level ($F_{3,21} = 3.23$). Orthogonal polynomial analysis of linear trend revealed that the relation between number of reinforcements and total extinction responses was significant beyond the .01 level ($F_{1,7} = 13.6$). These statistical tests lend added support to the reliability of the direct relationship indicated in Fig. 1. They also suggest that the inversion between 42 and 78 reinforcements may not be a real one, since the mean difference between these two points was small and insignificant.

The middle curves of Fig. 1 present group-extinction data relating probability of at least one response during each stimulus presentation to the number of reinforcements given each stimulus. In each session of extinction, counters tabulated the number of stimulus presentations during which at least one response occurred; the total for each stimulus was expressed as a decimal fraction of the total number (20) of presentations of that stimulus. For example, if a subject responded at least once to 15 different extinction presentations of the 78-reinforcement stimulus and not at all to the other 5 presentations of that stimulus, the probability of at least a single response during each presentation of that stimulus was 0.75.

Figure 1. Group curves plotting three different measures of resistance to extinction as a function of number of reinforcements during conditioning. Separate functions are shown for each day of extinction.

The probability data plotted in Fig. 1 were calculated for the group by first pooling all the individual data and then calculating group probabilities.

Response probabilities plotted as a function of number of conditioning reinforcements in Fig. 1 indicate a negatively accelerated, positive relationship on both days of extinction. On the average, probabilities were two to three times higher on the first day of extinction than on the second. Analysis of variance of these data, pooled for both days of extinction, showed significant differences among subjects ($F_{7,21} = 11.79$) and among number of conditioning reinforcements ($F_{3,21} = 5.92$) at the .01 level of confidence. Tests of linear trend showed the response-probability function of Fig. 1 to be significant at well beyond the .01 level ($F_{1,7} = 28.3$).

Latencies (in seconds) of the first response to each stimulus presentation were calculated for all extinction trials in which at least one response occurred. Then, mean latencies of

response to each of the four stimuli were determined for each subject. Since the different stimuli were not responded to equally in extinction (middle figure, Fig. 1), the *N*'s used to obtain these mean latencies were unequal and occasionally very small. The reciprocal of the group mean latency for separate days of extinction is plotted in the lower panel of Fig. 1. On Day 1 there is no hint of a relation between number of reinforcements and latency reciprocal, but on Day 2 there is the suggestion of a steadily increasing function. Analysis of variance, however, revealed no significant differences between any of the data points in either day's function.

As was mentioned earlier, the functions of Fig. 1 represent group data for eight individuals, each of which was exposed to all four values of the independent variable. This method permits an examination of the separate individual extinction functions, as is given in Fig. 2 for the response-probability and total-extinction-responses measures discussed above. No single subject in Fig. 2 demonstrates a response probability function just like that of the grouped data, and several diverge from the group trend. However, seven of the eight subjects show a more or less increasing function; i.e., the mean of the two largest reinforcement values is higher than that of the two lowest reinforcement values (dotted line, Fig. 2).

Individual functions relating number of extinction responses to number of conditioning reinforcements also suggest an increasing function, although two of the eight subjects show rather large decreases between 42 and 78 reinforcements. These decreases account for the inversion in the group function (Fig. 1) between these two values. Just as for the response-probability measure, no single individual displays a function which resembles the group function to any great extent.

Individual functions relating response latency to number of reinforcements were too variable to justify any sort of conclusion as to their shape or form, and so are not plotted here.

The functions of Fig. 2 were separately examined to determine whether any individual effects could be explained primarily on the basis of intrasubject generalization gradients. The question was: In extinction, would each subject be more likely to respond to colors closest in wavelength to the most frequently reinforced color, irrespective of the number of reinforcements with which each was correlated during conditioning? Such an effect was not apparent; however, the estimation of extinction generalization gradients after unequal training to four test stimuli is not an easy problem to solve on the basis of current data (Guttman, 1959; Kalish & Guttman, 1959).

Strong color preference of individual subjects might have provided another possible source of variability in the functions of Fig. 2. The records of each bird during conditioning and extinction were examined for such preferences. During conditioning, three or four subjects gave evidence of a slight "aversion" to the orange stimulus, as indicated by a few long latencies of response to this particular color. In the extinction tests, three of these birds (No. 37, 95, and 96) showed reversals of the group trend at the reinforcement frequency correlated with the orange stimulus (78, 18, and 18 reinforcements, respectively). These reversals suggest that aversions of this sort may have influenced these individual functions.

No systematic differences in mean latency of response to the four different stimuli were observed during conditioning. Response strength to each of the four stimuli before extinction, as indicated by this latency measure, thus was not correlated with the differential extinction scores. However, since latency measures in extinction did not reveal a clear relation with number of reinforcements, it is unfortunate that only this measure is available for estimating response strength prior to extinction.

Figure 2. Individual curves relating total extinction responses and probability of an extinction response to number of conditioning reinforcements. Data are combined for both days of extinction. Dotted lines connect the mean score for 6 and 18 reinforcements with the mean score for 42 and 78 reinforcements.

EXPERIMENT I: DISCUSSION

This experiment has shown that resistance to experimental extinction, as measured by total extinction responses and response probability, is an increasing function of the number

of reinforcements. The response-probability curve, for the grouped data in particular, exhibits the same sort of negatively accelerated relationship as was found by Williams (1938) and Perin (1942). This relationship was later used by Hull (1943) as one of the fundamental empirical curves in his definition of habit strength. Just as was indicated in the Perin-Williams data, resistance to extinction apparently approaches an asymptote after 50 to 80 reinforcements. The Perin and Williams functions were obtained in experiments which required the use of 160 and 140 subjects, respectively. However, the present study suggests that it may be possible and even more efficient to obtain an equivalent group function through the use of a much smaller number of subjects, if each is exposed to several values of the number-of-reinforcements variable.

The present method permitted an examination of resistance-to-extinction functions in each individual subject. Although it seems justified to state that these functions generally show a direct relation between number of reinforcements and resistance to extinction, clearly a good deal of difference exists between each function and any other. In addition, clearcut divergences from the group trend appear in several individual data points. Granted that each individual function cannot be expected to resemble all the others nor to show exactly the same relationship as the grouped data, it is still possible to point to several extraneous sources of individual variability. The difficulties involved in controlling for individual color preferences (e.g., see Reid, 1958, for additional information on color preferences in the pigeon) and for generalization phenomena have already been mentioned. These difficulties suggest that some method of estimating the contribution of these factors is needed to clarify the exact nature of the resistance-to-extinction functions. Generalization tests (Guttman & Kalish, 1956) and color-preference data might be obtained from each subject in a preliminary phase of the experiment, followed by prolonged extinction (Bersh, Schoenfeld, & Notterman, 1950), and only then, experimentation with the procedure outlined in the present experiment.

The rather small total number of extinction responses to all stimuli combined (ranging from 91 responses to 582 responses for the eight subjects) is most likely due to the fact that the subjects were regularly reinforced for key pecking and would be expected to emit many fewer responses than subjects which had been tested in extinction after intermittent-reinforcement schedules, as in Guttman and Kalish's study (1956) and in Experiment II of the present study.

EXPERIMENT II

Jenkins and Stanley (1950) have reviewed a large number of studies which support the general conclusion that resistance to extinction is greater after partial than after continuous reinforcement. In practically all the summarized experiments, several groups of subjects were used in the experimental design. Each group was conditioned under a different reinforcement schedule and then exposed to an extinction test that was the same for all groups.

The present experiment was designed to produce individual behavioral functions relating resistance to extinction to the probability of reinforcement during conditioning (here, the mean number of responses or variable ratio required for reinforcement). Boren (1953), Mowrer and Jones (1945), and Skinner (1938) have all investigated the relation between the fixed-ratio requirement during conditioning and resistance to extinction; they have indicated that as the fixed-ratio requirement increases, resistance to extinction increases. Several

hypotheses have been presented in explanation of this effect. Notable among them are the response-unit hypothesis of Mowrer and Jones and the generalization-decrement hypothesis, as discussed in Jenkins and Stanley.

In addition to providing data on whether intrasubject functions are of the same form as group functions, an examination of individual behavioral relations may allow further tests of these hypotheses.

EXPERIMENT II: METHOD

Subjects.

The subjects were four¹ barren, White Carneaux hen pigeons, ranging from 3 to 6 years old.

Apparatus.

The same test chamber and accessory equipment were used as in Experiment I.

Procedure

Preliminary. Just as in Experiment I, the four subjects were successively scheduled for punchboard experience, adaptation to the experimental chamber, magazine training, and pecking training at the grain-dotted, nonilluminated and noncolored response key.

Conditioning. All subjects were then exposed to the following conditioning procedure, under which they remained for 17 consecutive daily sessions. Each session consisted of 20 stimulus (i.e., key color) periods, five presentations for each of four colors, which alternated with 1-minute blackout periods throughout the session. During Color 1, key pecking was regularly reinforced (i.e., *every* key peck was immediately followed by a 3-second grain presentation). During Color 2, every fourth response on the average was reinforced (variable ratio, 4:1). During Color 3, every tenth response on the average was reinforced (variable ratio, 10:1). Finally, during Color 4, no responses were reinforced (extinction). A total of five reinforcements could be obtained each time one of the reinforced colors (No. 1-3) appeared on the key, and each of these colors continued to illuminate the key until the fifth reinforcement was obtained and the intertrial blackout began. Nonreinforced Color 4 remained on for 2 minutes per presentation. By the above procedure, each subject obtained 25 reinforcements per day on each of three reinforced colors (five reinforcements on each of five presentations) and thus equal numbers of reinforcements on each of the three colors over the entire course of conditioning. The only difference among the stimulus conditions lay in the number of responses required for reinforcement in each.

Color preferences were controlled in a manner similar to that in Experiment I. For half the subjects, responding in the orange stimulus was rewarded on a 1:1 ratio, red on a 4:1 ratio, and blue on a 10:1 ratio; green was unreinforced. The other subjects had green 1:1, blue 4:1, orange 10:1, and red unreinforced.

Two different randomized orders of presentation of the stimuli were available, and different orders were programmed on alternate days for each subject.

Extinction. Extinction sessions followed the same general method as in Experiment I. Each of the four colored stimuli appeared on the key 25 times during each of three extinction tests, carried out on 3 successive days; the first test took place 24 hours after

¹Two other birds were initially included. However, during conditioning, they persisted in pecking at the response key very often during the time the grain magazine was available, and so were dropped from the experiment.

the last conditioning session. The stimuli thus occurred equally often (75 times each) over the duration of the 3-day test period. Stimulus presentations lasted 30 seconds, irrespective of the subject's responding, and were followed by 10-second blackouts terminated by the presentation of the next stimulus. Orders of color presentation were randomized within a single daily test and were different from day to day for each subject. Total responses in the presence of each stimulus were tabulated as a measure of relative resistance to extinction for responding in each stimulus.

EXPERIMENT II: RESULTS

Figure 3 presents both individual and group functions relating variable ratio during conditioning to total extinction responses (combined for the 3 days of extinction). All individual curves, as well as the grouped data, show a direct relationship between the two variables. Besides showing differences among subjects significant at the .05 level of confidence

Figure 3. Resistance to extinction as a function of the variable ratio during conditioning. The four individual curves are included, as well as group results.

($F_{3,6} = 5.58$), an analysis of variance performed on the group extinction data (omitting the 0:1 ratio which would have ensured significance) revealed significant differences among variable ratios at the .01 level ($F_{2,6} = 11.62$). The linear trend of the Fig. 3 group results for the three reinforced colors was significant beyond the .025 level ($F_{1,3} = 18.8$).

Both Mowrer and Jones (1945) and Boren (1953) made a test of the Mowrer-Jones hypothesis by calculating the number of response units occurring during extinction. These investigators calculated the number of response units in extinction by dividing the total number of extinction responses for each group of subjects by the fixed ratio during conditioning for each group. A negatively accelerated, decreasing function relating fixed ratio to this response-unit measure was obtained, contrary to the linear function with a zero slope that the Mowrer-Jones hypothesis in its strictest sense implies. The present study involved variable ratios during conditioning rather than fixed ratios, but the same finding is apparent during extinction. As the VR increased from 1:1 to 4:1 to 10:1, the group mean response-unit declined from 149.5 responses to 58.2 responses to 43.1 responses. Individual functions all showed essentially the same relation.

EXPERIMENT II: DISCUSSION

For both individual and grouped data, the results of the present experiment indicate a greater resistance to extinction for intermittently reinforced behavior than for continuously reinforced behavior. The relation obtained between variable ratio during conditioning and resistance to extinction thus confirms the major findings of Mowrer and Jones (1945) and Boren (1953) who used separate groups (total N equalled 30 and 36, respectively, for the two investigations) to obtain each extinction data point. The grouped data of Fig. 3, plotted in the same manner as Mowrer and Jones' and Boren's final results, suggest a fairly linear relation between the two variables, as these prior workers also found. It is important to note, however, that reinforcements were received on a variable-ratio schedule in the present experiment, while the former studies primarily involved the use of fixed-ratio schedules. Mowrer and Jones did train one group of subjects on a variable-ratio schedule with a mean number of responses per reinforcement (2.5) midway between two of their fixed-ratio values. Because the results for this group did not differ radically from predictions based purely on the fixed-ratio data, these investigators concluded that discontinuity of reinforcement (continuous vs. intermittent) rather than irregularity (fixed vs. variable) was much more critical in accounting for the resistance-to-extinction data. Ferster and Skinner (1957) have pointed out that the differential reinforcement of high rates is the major characteristic of both fixed- and variable-ratio schedules.

The individual functions shown in Fig. 3 appear to be relatively free of the sort of variability that distinguished the individual data of Experiment I. Except for the inversion at the 4:1 ratio in Bird No. 20's function, all four individual curves reflect fairly well the grouped data and the similar ratio-schedule results of Mowrer and Jones, Skinner (1938), and Boren. The most important reason for these differences between Experiments I and II probably lies in the fact that Experiment II subjects were exposed to a long series of conditioning sessions on a procedure which was likely to develop clear discriminations among the four test stimuli; i.e., different schedules of reinforcement were programmed in the presence of each stimulus. In Experiment I the response-reinforcement relation was the same for all stimuli. This fact, together with the necessarily much smaller number of stimulus presentations during conditioning, could not be expected to enable as powerful

stimulus control as in Experiment II. The virtual absence of extinction responding to the one nonreinforced color in Experiment II is indicative of the efficiency of each subject's stimulus discriminations, and suggests that complicated interactions due to color preferences, stimulus generalization, or response induction, etc., actually had little influence during the extinction tests.

The present method indicates no new conclusions can be drawn as to the relative explanatory power of the various hypotheses used to explain the differential effects of continuous and partial reinforcement on extinction responding. The response-unit hypothesis, corrected for the decrease in extinction response-units with increasingly more "effortful" ratios (as Mowrer and Jones suggest), could easily be applied in the present situation: Different units or patterns of response are conditioned to each of the four test stimuli; and the larger the unit (here, the variable ratio), the larger the number of responses emitted in extinction to the respective stimulus. This explanation of the extinction effects is closely related to that of Spence (1956), who considers the length of the conditioned instrumental chain to be the critical factor in accounting for differential extinction effects in the free-responding situation.

The generalization-decrement hypothesis could equally well apply to the present data. The conditions during the extinction test are more like those of the 10:1 conditioning ratio than the 1:1 ratio, since unreinforced key pecking occurs in both conditioning and extinction for the 10:1 ratio and not for the 1:1 ratio. By such reasoning, more extinction responses ought to be made to the stimulus correlated with the 10:1 ratio, etc. As long as one assumes that the four test stimuli were discriminated during conditioning, for which ample evidence was presented above, both the response-unit and generalization-decrement explanations appear to be equally valid for the present experimental effects as well as for numerous prior results.

EXPERIMENTS I AND II: SUMMARY

A technique for obtaining both individual and group functions which relate resistance to extinction to various independent variables was discussed, and data was presented from two experiments in which this method was used.

(1) During conditioning, individual pigeons were given different numbers of regular reinforcements for key pecking at four different key colors. Extinction responding to the different colors indicated a direct relation between number of reinforcements and resistance to extinction. The grouped and individual results were compared with prior data obtained through procedures with separate groups.

(2) A second experiment showed that resistance to extinction was an increasing function of the variable-ratio requirement during conditioning. Individual and group data were compared, and the applicability of different hypotheses to account for the obtained differences between continuous and partial reinforcement was examined.

REFERENCES

- Bersh, P., Schoenfeld, W. N., and Notterman, J. The effect of reinforcement history on extinction after reconditioning. *Science*, 1950, **112**, 743-745.
- Boren, J. Response rate and resistance to extinction as functions of the fixed ratio. Unpublished doctoral dissertation, Columbia Univer., 1953.
- Estes, W. K. Problem of inference from curves based on group data. *Psychol. Bull.*, 1956, **53**, 134-140.

- Ferster, C. B. The use of the free operant in the analysis of behavior. *Psychol. Bull.*, 1953, **50**, 263-274.
- Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Guttman, N. Generalization gradients around stimuli associated with different reinforcement schedules. *J. exp. Psychol.*, 1959, **58**, 335-340.
- Guttman, N., and Kalish, H. Discriminability and stimulus generalization. *J. exp. Psychol.*, 1956, **51**, 79-88.
- Hanson, H. Effects of discrimination training on stimulus generalization. *J. exp. Psychol.*, 1959, **58**, 321-334.
- Hull, C. L. *Principles of behavior*. New York: D. Appleton Century Co., 1943.
- Kalish, H., and Guttman, N. Stimulus generalization after training on three stimuli: a test of the summation hypothesis. *J. exp. Psychol.*, 1959, **57**, 268-272.
- Jenkins, W. O., and Stanley, J. C. Partial reinforcement: a review and critique. *Psychol. Bull.*, 1950, **47**, 193-234.
- Mowrer, O. H., and Jones, H. Habit strength as a function of the pattern of reinforcement. *J. exp. Psychol.*, 1945, **35**, 293-311.
- Perin, C. T. Behavior potentiality as a joint function of the amount of training and the degree of hunger at the time of extinction. *J. exp. Psychol.*, 1942, **30**, 93-113.
- Reid, R. L. Discrimination-reversal learning in pigeons. *J. comp. physiol. Psychol.*, 1958, **51**, 716-720.
- Schrier, A. M. Comparison of two methods of investigating the effect of amount of reward on performance. *J. comp. physiol. Psychol.*, 1958, **51**, 725-731.
- Sidman, M. A note on functional relations obtained from group data. *Psychol. Bull.*, 1952, **49**, 263-269.
- Skinner, B. F. *The behavior of organisms*. New York: D. Appleton Century Co., 1938.
- Skinner, B. F. *Cumulative record*. New York: Appleton-Century-Crofts, 1959.
- Spence, K. W. *Behavior theory and conditioning*. New Haven: Yale University Press, 1956.
- Williams, S. B. Resistance to extinction as a function of the number of reinforcements. *J. exp. Psychol.*, 1938, **23**, 506-522.

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