*EXTINCTION OF A DISCRIMINATIVE OPERANT
FOLLOWING DISCRIMINATION LEARNING
WITH AND WITHOUT ERRORS¹*

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Different groups of pigeons were trained to respond to red and not to green with and without errors (responses to green) under a free operant procedure, in which responding to red was intermittently reinforced, and under a trial procedure in which all responses to red were reinforced. The response to red was then extinguished under a procedure in which the discriminative stimuli were successively alternated as during discrimination training. The performances of those birds that learned the discrimination without errors under the trial procedure were seriously disrupted during extinction; the birds persistently responded to green for the first time. The performances of those subjects that learned the discrimination without errors under the free operant procedure were not disrupted during extinction. In a second experiment, the same discrimination was trained without errors under a trial procedure in which the response to red was intermittently reinforced. Extinction did not disrupt discrimination performance. Thus, errorless discrimination performance was shown to remain intact during extinction so long as the response to red was intermittently reinforced during discrimination training.

A series of earlier studies showed that performances following discrimination learning with and without errors (responses to S-) differ in several respects. Gross "emotional" responses (Terrace, 1966a), drug-induced disruption of discrimination performance (Terrace, 1963a), behavioral contrast (Terrace, 1963b, 1963c, 1966a), post-discrimination generalization peak shifts (Terrace, 1964), and gradients of inhibition with minima at S- (Terrace, 1966b) were observed to occur only after discrimination learning with errors. These phenomena were in each case assumed to result from the aversiveness of S- that was established by the occurrence of non-reinforced responding to S-.

It is conceivable, however, that there exist other differences following discrimination learning with and without errors that are not

immediately related to the aversiveness of S-. The present experiments stemmed from the hypothesis that performances during extinction following discrimination learning with and without errors may differ and that these differences are the result of variables other than the aversiveness of S-.

Experiment I is the final (but unpublished) phase of an earlier study on errorless discrimination learning (Terrace, 1963b). Briefly stated, Exp. I was concerned with the extinction of the response to S+ following discrimination learning with and without errors. All subjects in Exp. I were trained on a successive discrimination between a red (S+) and a green (S-) circular patch of light. Half of the subjects were trained by a trial procedure that reinforced each response to S+ and terminated each trial after a single response. The remaining subjects were trained by a free operant procedure in which responding to S+ was intermittently reinforced and which allowed many responses to occur during each presentation of S+ or S-.

In the case of both the trial and the free operant groups, one sub-group was trained to discriminate between S+ and S- without errors.² In each case this was accomplished by

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²While none of the subjects of Exp. I acquired a discrimination with zero errors, none of the subjects in

starting discrimination training immediately after the key-peck response had been conditioned with a large $S+ - S-$ difference that was progressively reduced to the final $S+ - S-$ value. Because discrimination training began early in the conditioning history of these subjects, with a pair of discriminative stimuli, the difference between which was progressively reduced, this procedure was called the "early-progressive" procedure. The remaining subjects of the trial and free operant groups were trained on one of three variations of the "early-progressive" procedure: "early-constant", "late-progressive", and "late-constant". The relevant details of these procedures are described below.

Experiment II employed a modification of the early-progressive procedure that was followed under the trial paradigm. As in Exp. I, the value of the probability of reinforcement for responding to $S+$ was 1.0 at the start of discrimination training. However, during the course of discrimination training, the probability of reinforcement for responding to $S+$ was gradually reduced from 1.0 to 0.10. This was done to provide the subjects that made no errors during the acquisition of the discrimination with a history of intermittent reinforcement for responding to $S+$.

EXPERIMENT I

METHOD

Subjects

Twenty four male White Carneaux pigeons had all served in an earlier study of discrimination learning (Terrace, 1963*b*). The specific history of each subject is discussed below. Each

bird was maintained at 80% of its free-feeding body weight throughout its experimental history.

Apparatus

An experimental chamber containing a response key and food and stimulus-presenting devices, was identical to the apparatus used in an earlier study (Terrace, 1963*b*). The stimulus-presenting device, adapted from an Industrial Electrical Engineering Corporation display unit, was mounted directly behind the key and could transilluminate the key with either a red ($S+$) or a green ($S-$) light.

Procedure

The conditioning history of each subject is described in detail in Terrace (1963*b*). This study was primarily concerned with: (1) variables that affect the number of errors that occurred during the acquisition of a discrimination, and (2) interactions within multiple schedules (*e.g.*, behavioral contrast, *cf.* Reynolds, 1961). As a result, these subjects had a relatively complex history of alternation between differential and non-differential reinforcement training before extinction. The essential details of each group's conditioning history are summarized below. To avoid possible confusion, the reader is again reminded that the only portion of the subjects' training history not reported previously is the extinction procedure. The sketchy summaries of the non-differential and differential reinforcement history of each subject described below are intended solely to provide a basis for interpreting the results of the extinction procedure.

TRIAL PROCEDURE

Each session consisted of a series of discrete, automatically scheduled trials. A trial was defined as the period of time during which the response key was transilluminated by either a red ($S+$) or a green ($S-$) light. All trials were terminated by a response or by a failure to respond within 5 sec of the onset of the trial. Thus, only one response could occur during each trial. Responses during an $S+$ trial were immediately reinforced. Between trials, the houselight remained on, but the key was dark. The duration of the intertrial interval was

Exp. II, which were trained on a more refined version of the training procedure that progressively introduced $S-$, made *any* errors in acquiring the same discrimination. The same discrimination procedure was successful in 12 out of 12 instances in a study carried out subsequent to Exp. I (Terrace, 1963*c*) and also in experiments using the free-operant procedure (Terrace, 1964, 1966*a*). It should be noted also that the performances of those subjects that learn a discrimination with zero or near-zero number of errors differ in many respects from those that make many errors. For these reasons, discriminations acquired with zero or near-zero number of errors will both be referred to as discriminations acquired without any errors.

determined by an irregular series of intervals with a range of 9 to 30 sec and a mean of 15 sec. Responding during the intertrial interval delayed the onset of the next trial for 10 sec.

Each subject was given both non-differential and differential reinforcement training. A non-differential reinforcement session consisted of 60 S+ trials. A differential reinforcement session consisted of 60 S+ and 60 S- trials. The S+ and S- trials alternated in an irregular series except when a correction procedure was invoked. The correction procedure required S+ trials, during which no response occurred, and S- trials, during which responses did occur, to repeat as the next trial. Both the S+ and the S+-S- sessions were terminated after 60 reinforcements. The upper portion of Table I summarizes the numbers of sessions using each procedure and their order of occurrence for each experimental group. The order of occurrence of the S+ (non-differential reinforcement) and the S+-S- (differential reinforcement) sessions depended on whether or not S- was introduced immediately after the key peck was conditioned ("early"), or after extended S+ training ("late"). If S- was introduced early, discrimination training began during the first experimental session. The sequence of training conditions under the early condition was: S+-S-, S+, S+-S-. If S- was introduced

late, discrimination training began after 14 S+ sessions. Under the late condition, the sequence of training conditions was: S+, S+-S-, S+, S+-S-.

Discrimination Training

The procedures described in the following section were used to train the red-green discrimination during the first series of S+-S- sessions. The second series of S+-S- sessions began abruptly with no special training procedure.

Early-progressive discrimination training (Subjects 118, 119, 120). Discrimination training began immediately after the key-peck response had been conditioned. During the first session, S- was progressively changed from a dark key of 0.5-sec duration to a fully intense green key of 5-sec duration.

Early-constant discrimination training (Subjects 139, 144, 145). Discrimination training began immediately after the key-peck response had been conditioned. From the outset of discrimination training, S- was at full intensity and of 5-sec duration.

Late-progressive discrimination training (Subjects 140, 142, 146). Discrimination training began after 14 S+ sessions. The changes in the intensity and the duration of S- were the same as those made for the early-progressive group.

Table 1

Sequence and Number of S+, S+-S-, and Ext. Sessions for Trial and Free-Operant Groups

Type of Session (in order of occurrence)	Extinction			
	Early-Progressive Group (118, 119, 120)	Early-Constant Group (139, 144, 145)	Late-Progressive Group (142, 146, 140)	Late-Constant Group (141, 128, 127)
TRIAL PROCEDURE				
S+			14	14
S+-S-	14	14	14	14
S+	14	14	7	7
S+-S-	14	14	14	14
Extinction	20	20	20	20
FREE OPERANT PROCEDURE				
	(114, 116, 155)	(150, 151, 152)	(147, 148, 149)	(131, 132, 154)
S+			21	21
S+-S-	21	21	14	14
S+	14	14	7	7
S+-S-	7	7	14	14
Extinction	7	7	7	7

Late-constant discrimination training (Subjects 127, 128, 141). Discrimination training began after 14 S+ sessions. S- was initially at full intensity and of 5-sec duration.

Extinction

Following the second series of discrimination sessions, each group received 20 extinction sessions. During each extinction session, S+ and S- alternated as previously, but no responses were reinforced. A response made during an S- trial resulted in the repetition of that trial. Responding or not responding during an S+ trial, however, had no effect on the nature of the next trial. Each extinction session was terminated after 60 S+ trials had occurred.

FREE OPERANT PROCEDURE

The free operant and the trial procedures differed with respect to (1) the probability of reinforcement for a response to S+ and (2) the number of responses that could occur during each presentation of a discriminative stimulus. Under the trial procedure, the probability that a response to S+ would be reinforced was always 1.0 and a single response terminated the presentation of each S+ and S-. In the free operant procedure, however, responses to S+ were intermittently reinforced, and many responses could occur during each presentation of S+ and S-.

Four groups of pigeons were used. As in the trial procedure, each group differed with respect to when and how discrimination training began. During discrimination training, a two-component, multiple variable-interval extinction (*mult VI ext*) schedule was used. During the first component, the key was red (S+), and responses were reinforced on a VI 1-min schedule of reinforcement. The S+ component lasted 3 min and was immediately followed by the onset of S-. During S-, the key was green and responding was never reinforced. The duration of the S- component was, in part, controlled by whether or not responding to S- occurred. If no responding to S- occurred, the second component lasted 3 min. If responding to S- did occur, the onset of the next S+ component was delayed until 3 min without a response to S- had occurred. This correction procedure was used to minimize the possibility of accidental reinforcement of

responding to S- by the subsequent presentation of the S+ component.

The order of occurrence of the S+ and the S+—S- sessions depended on whether or not S- was introduced early or late. The number of each type of session and their order of occurrence for the four experimental groups appear in the lower half of Table 1. Both the non-differential (S+) and the differential (S+—S-) reinforcement sessions were terminated after 60 reinforcements had occurred.

Discriminating Training

The procedures described in the following section were used to train the red-green discrimination during the first S+—S- series. As was the case for the trial procedure, the second S+—S- series began abruptly with no special training procedure.

Early-progressive discrimination training (Subjects 114, 116, 155). Discrimination training began approximately 30 sec after the key peck had been conditioned. During the first three sessions, the schedules of reinforcement associated with S+ were changed from continuous reinforcement (CRF) to VI 30-sec to VI 60-sec and S- was changed from a dark key of 5-sec duration to a fully intense green key of 3-min duration.

Early-constant discrimination training (Subjects 150, 151, 152). Discrimination training started for this group also during the first experimental session. The duration and the brightness of S-, however, were initially at their maximum values: 3 min and full intensity, respectively. Approximately 30 sec after the key peck had been conditioned, the schedule of reinforcement was changed from CRF to VI 30-sec. Three minutes later the first S- component began, and the S+—S- procedure went into effect. After the first session, responding in the S+ component was reinforced on a VI 60-sec schedule.

Late-progressive discrimination training (Subjects 147, 148, 149). Discrimination training was started after 21 S+ sessions. The changes in the intensity and the duration of S- were the same as those made for the early-progressive group. Throughout discrimination training, the duration of the S+ component was 3 min, and the schedule of reinforcement during the S+ component was VI 60-sec.

Late-constant discrimination training (Subjects 131, 132, 154). Discrimination training

was started after 21 S+ sessions. S- was initially at full intensity and of 3-min duration.

Extinction

Following the second series of S+—S- sessions, each group was given seven extinction sessions. The only differences between the S+—S- and the extinction sessions were that (1) no responses to S+ were reinforced, and (2) each extinction session was terminated after 20 S+—S- cycles.

RESULTS

Before considering the extinction performances of the trial and the free operant groups, it is important to consider first the number of errors that each subject made during discrimination training. This information is summarized in Table 2 along with the number of responses to S+ and to S- emitted by each subject during extinction, the median latency of the response to S+ during the last five S+—S- sessions of each subject trained under the trial procedure, and the mean rate of responding to S+ during the last five sessions of each subject trained under the free operant procedure. The analysis of performance during extinction that follows below considers (1)

the number and distribution of responses to S+ and to S- during extinction, (2) the relationship between the number of errors during discrimination training and the number of responses to S+ and to S- during extinction, and (3) the relationship between the number of responses to S+ during extinction and either the latency of the response to S+ at the end of discrimination training (trial group) or the rate of responding to S+ at the end of discrimination training (free operant group).

Trial procedure: responding to S-. The cumulated number of responses to S+ and to S- emitted by each subject over each extinction session is shown in Fig. 1. The most striking aspect of these results is the performance of the early-progressive group, which had acquired the discrimination between S+ and S- with virtually no errors. Each of these subjects made at least five times as many responses to S- during extinction as they had during discrimination training. It should also be noted that during extinction the number of responses to S- of the early-progressive group approached the number of responses to S- made during acquisition by the subjects of the late-constant group, the group that made the largest number of responses to S- during discrimination training. The Spearman rank-

Table 2

Discrimination Training Procedure	Trial Procedure					Free Operant Procedure				
	Bird No.	Discrimination Training			Discrimination Training					
		No. of Re- sponses to S—	Median Latency of Re- sponding to S+ (sec)	Extinction		Bird No.	No. of Re- sponses to S—	Mean Rate of Respond- ing to S+ (resp/ min)	Extinction	
				No. of Responses					No. of Responses	
				to S—	to S+				to S—	to S+
Early- Progressive	118	8	0.74	40	400	114	26	45	24	1648
	119	4	0.96	299	411	116	39	52	41	8105
	120	3	0.38	286	558	155	42	63	34	4455
Early- Constant	139	44	1.32	16	279	150	812	128	182	9660
	144	40	0.91	19	197	151	376	94	214	5826
	145	187	0.65	0	80	152	405	91	164	7889
Late- Progressive	142	20	1.12	133	309	147	1418	78	86	6483
	146	38	1.26	0	79	148	855	85	74	6113
	140	25	0.97	4	97	149	1091	130	103	4260
Late- Constant	141	176	0.63	24	475	131	5056	83	925	18231
	128	295	0.82	45	208	132	2018	118	471	9920
	127	314	0.92	21	202	154	4425	125	486	4061

ABRUPT EXTINCTION — TRIAL PROCEDURE

Fig. 1. The cumulated number of responses of each subject trained under the trial procedure during 20 extinction sessions.

order correlation coefficient between responding to S- during discrimination training and during extinction was -0.37 .

By the eighth extinction session, each of the subjects of the early-progressive group began to respond to S-. In two out of three cases, the onset of responding to S- occurred one or two sessions before the session in which the probability of responding to S+ fell below 1.0 for the first time. Subject 120, for example, responded to each of the 60 S+ presentations during each of the first eight extinction sessions. During the ninth session, Subject 120 made only 48 responses to S+. Subject 120 began responding to S- during the eighth extinction session during which it responded to S- 51 times. Subject 118 began responding to S- during the sixth extinction session, the

second session during which fewer than 60 responses to S+ had occurred.

Subject 119, an apparent exception to this rule, began responding to S- during the second extinction session. It was not, however, until the sixth and seventh extinction sessions that the probability of Subject 119's responding to S- reached its maximum value. The sixth extinction session was the first in which Subject 119 did not respond on all of the S+ trials.

A similar pattern of responding to S- can be seen in the performance of Subject 142 of the late-progressive group. This subject responded to S- on only 20 trials during discrimination training, the smallest number of responses outside of the early-progressive group. Subject 142 began responding to S-

during the third extinction session. The maximum frequency of responding to S- occurred during the fifth and sixth extinction sessions. The probabilities of an S+ response during the second, third, fourth, fifth, and sixth sessions were, respectively, 0.72, 0.92, 0.70, 0.73, and 0.30. It thus appears that the highest frequency of responding to S-, during extinction, of those subjects that learned the discrimination with a few responses to S- occurred at the time that responding to S+ began to weaken.

None of the remaining subjects (the early-constant group, Subjects 140 and 146 of the late-progressive group and the late-constant group) emitted more than 45 responses to S- during extinction. Responding to S- in each of these instances was sporadic (*cf.* Fig. 1). Thus, unlike the sharply rising response functions of the subjects that learned the discrimination with few errors, the S- response functions of the subjects that learned the discrimination with many errors showed a gradual rise during the course of extinction.

Responding to S+. The early-progressive group made the largest number of responses to S+ during extinction. Subjects 120, 119, and 118 of the early-progressive group made, respectively, the first, third, and fourth highest number of responses to S+. With the exception of Subject 141 of the late-constant group, the number of responses to S+ of the remaining groups were uniformly distributed among the early-constant, the late-progressive, and the late-constant groups.

Correlation between latency of responding to S+ during discrimination training and responding to S+ and to S- during extinction. The latency of the response to S+ at the end of discrimination training (*cf.* Table 2) was a poor predictor of the number of responses to S+ and to S- during extinction. The Spearman rank-order correlation coefficients between latency of responding to S+ at the end of discrimination training and the number of responses to S+ and to S- during extinction were, respectively, +0.37 and +0.33.

Free operant procedure: responding to S-. The cumulated number of responses emitted by each subject to S+ and to S- during each extinction session is shown in Fig. 2. It should be noted that in Fig. 2 the left-hand ordinate is larger than the right-hand ordinate by a factor of 20.

The accuracy of discrimination performance of the early-progressive group, the group that learned the discrimination with a near-zero number of errors, was not disrupted by extinction. Table 2 and Fig. 2 show that responding to S- of the subjects of the early-progressive group remained at a near-zero level throughout extinction. Thus, the effects of extinction on errorless discrimination performance following discrimination training under a free operant procedure differed from the effects of extinction following discrimination training under a trial procedure. Errorless performance was disrupted only during extinction following training under a trial procedure.

The cumulated response to S- functions shown in Fig. 2 indicate that there was no overlap of the number of responses emitted to S- among the subjects of each group. The smallest number of responses to S- was made by the subjects of the early-progressive group (range: 24 to 41). Between these extremes were the subjects of the late-progressive group (range: 74 to 103) and the early-constant group (range: 164 to 214).

The number of responses emitted to S- during extinction was correlated with the number of responses to S- during discrimination training. (Spearman rank-order correlation coefficient = +0.78). The only reversal between the number of responses to S- during discrimination training and extinction involved the early-constant and late-progressive groups. Curiously, the subjects of the early-constant group made fewer responses to S- during discrimination training than did any of the subjects of the late-progressive group. During extinction, however, all subjects of the early-constant group made more responses to S- than did any of the subjects of the late-progressive group.

Responding to S+. The number of responses to S+ during extinction did not differ across the four experimental groups. While the smallest number of responses to S+ was made by Subject 114 of the early-progressive group (1648 responses) and the largest number to S+ by Subject 131 of the late-progressive group (18,231 responses), there was much overlap among the four experimental groups trained under the free operant procedure.

Correlation between rate of responding to S+ during discrimination training and re-

ABRUPT EXTINCTION - FREE OPERANT PROCEDURE

Fig. 2. The cumulated number of responses to S+ and to S- of each subject trained under the free operant procedure during seven extinction sessions. Note that the scale of the ordinate on the left showing the cumulative number of responses to S+ differs from the scale of the ordinate on the right showing the cumulated number of responses to S- by a factor of 20.

sponding to S+ and to S- during extinction. The number of responses that occurred in extinction to S- showed little relation to the rate of responding to S+ at the end of discrimination training. The value of the Spearman rank-order correlation coefficient between the rate of responding to S+ at the end of discrimination training and the number of responses to S- during extinction was +0.38. A higher correlation was obtained, however, between the rate of responding to S+ at the end of discrimination training and the number of responses to S+ during extinction ($\Gamma = 0.58$).

DISCUSSION

The major finding of this experiment was that errorless discrimination performance was seriously disrupted during extinction following discrimination training in which the probability of reinforcement for responding to S+ was 1.0. Extinction following discrimination training in which responses to S+ were inter-

mittently reinforced had no adverse effect on errorless discrimination performance.

These results suggest that the abrupt transition from a probability of reinforcement for responding to S+ of 1.0 to 0.0, in going from discrimination training to extinction, was responsible for the disruption of errorless discrimination performance. The most obvious benefit of intermittent reinforcement of the response to S+ during discrimination training appears to be the establishment of what is popularly called "frustration tolerance".

Unfortunately, "frustration tolerance" carries with it only the weight of popular usage (cf. Rosenzweig, 1938, 1944; Freeman, 1948, p. 115; Keller and Schoenfeld, 1950, p. 91; Cofer and Appley, 1965, p. 331) and has not been the subject of an empirical or conceptual analysis. It seems clear, however, that intermittent reinforcement is one of the basic variables involved in establishing what various psychologists have referred to as frustration tolerance. Skinner (1938, p. 138) cited the relationship between "equanimity" (an apt

synonym for frustration tolerance) and intermittent reinforcement in describing the extinction process:

"The stability of reflex strength under periodic reconditioning and the prolongation of the extinction curve following it are important properties of normal behavior. They are responsible for a measure of equanimity in a world in which the contingency of reinforcing stimuli is necessarily uncertain. Behavior would be clumsy and inefficient if the strength of an operant were to oscillate from one extreme to another with the presence or absence of its reinforcement."

It should be noted that this analysis is also consistent with the generalization-decrement explanation of why resistance to extinction is greater after partial reinforcement than after regular reinforcement (*cf.* Kimble, 1961, pp. 299 ff). Just as the uncertainty of when reinforcement can occur increases the difficulty of discriminating between conditioning and extinction, this factor may also increase frustration tolerance by reducing anticipatory responses of when reinforcement might occur.

Given that frustration occurs when a reinforcement that has regularly followed a response is withheld, one would expect that frustration tolerance would be greater after irregular intermittent reinforcement than after continuous reinforcement. Experiment II attempted to establish frustration tolerance during discrimination training, in which a trial procedure is used, by gradually reducing the probability of reinforcement for responding to S+ during the course of discrimination training.

The results of Exp. I are also relevant to Jenkins' observation (1961) that non-reinforced responding to S- during the acquisition of a discrimination functions like intermittent reinforcement in a non-differential reinforcement situation by increasing resistance to extinction. Jenkins used three groups of subjects: (1) intermittent reinforcement, (2) discrimination training, and (3) continuous reinforcement. Each subject from the intermittent group was matched with a subject from the discrimination group. For each intermittent subject, both the number and the temporal location of non-reinforced trials were determined by the performance of the discrim-

ination subject with which it was matched. On those trials in which a discrimination subject responded to S-, reinforcement availability was cancelled for the subject of the intermittent group with which it was matched. The third group was given continuous reinforcement in the presence of one stimulus. No differences were observed between the intermittent and the discrimination groups with respect to the number of responses to S+ that occurred during extinction. Since all three groups had an equal number of reinforcements before extinction, these results demonstrated that the effect of unreinforced responses to S- (errors) during the acquisition of a discrimination was equivalent to the effect of intermittent reinforcement in that they both increased resistance to extinction by similar amounts. Jenkins concluded (1961, p. 115):

"discrimination training increased resistance to extinction over regular reinforcement. . . . [The results] further show that the pattern of intermittent reinforcement . . . which occurs in discrimination training is capable, when applied to a single stimulus, of producing an increase in resistance to extinction over regular reinforcement as large or larger than the increase resulting from discrimination training itself. . . . [This] implied that the increase in resistance to extinction is not directly related to the fact that S₁+ is eventually discriminated from S₂-. Rather, it is related to the occurrence of non-reinforced responses in the process of learning the discrimination. If the stimuli were very dissimilar, so that after training on S₁+, only a few responses were made to S₂-, then a smaller increase in resistance to extinction would be expected to result from discrimination training."

Jenkins' analysis of non-reinforced responding during discrimination training suggests that the resistance to extinction in the group that learned the discrimination without errors would be equivalent to the resistance to extinction of a group which had the same number of continuous reinforcements under non-differential reinforcement training. Unfortunately, the design of the present experiment did not provide a non-differential group that received continuous reinforcement. The de-

sign of this experiment did, however, allow a check of another implication of Jenkins' analysis. Since the number of responses to S- during discrimination training varied as a function of the discrimination training procedure, one would expect that the resistance to extinction of the response to S+ would vary directly with the number of responses to S- during discrimination training. The results obtained from the free operant group supported this prediction; the results obtained from the trial group did not.

For the free operant group, the number of responses to S- during discrimination training varied directly with the resistance to extinction of the response to S+ (Spearman rank-order correlation coefficient = +0.78). Thus, the greater the level of non-reinforced responding to S- during discrimination training, the larger the frequency of responding to S+ during extinction. It should, however, also be noted that an alternative account of the correlation between the number of responses to S+ and to S- during extinction is equally compatible with the results obtained in Exp. I. The resistance to extinction of the response to S+ was correlated, to a slightly lesser degree, with the rate of responding to S+ at the end of discrimination training. Since behavioral contrast (*cf.* Reynolds, 1961) occurred only in the case of those subjects that learned the discrimination with errors, and since the amount of contrast was generally related to the number of errors during discrimination training, it is not possible to distinguish between the rate of responding to S+ at the end of discrimination training and the number of errors during the formation of the discrimination in accounting for the resistance to extinction of the response to S+.

A different state of affairs emerged with respect to the relationship between the number of errors during discrimination training and the resistance to extinction of the response to S+ in the case of the trial group. It should be noted that the present trial procedure closely approximated Jenkins' procedure. It was, therefore, all the more surprising not to have obtained a relationship between the number of errors during discrimination training and the resistance to extinction of the response to S+.

Following discrimination training under the trial procedure, the resistance to extinc-

tion of the response to S+ was greatest for the early-progressive group, the group that acquired the discrimination with virtually no errors. The high resistance to extinction of the response to S+ following errorless discrimination learning may have been due to the emotional reaction generated by non-reinforcement. It should be remembered that until extinction training began, the subjects of the early-progressive group had virtually no history of non-reinforcement in the experimental situation. For those subjects that acquired the discrimination with errors, the emotional responses generated by non-reinforcement had presumably diminished in strength before the onset of extinction. In another experiment (Terrace, 1966c) it was shown that behavioral contrast and the peak shift, two characteristics of discrimination performance following discrimination learning with errors that were also presumed to result from extinction-induced emotional responses, diminished during extended discrimination training.

Emotional reactions have been invoked by various researchers to account for a temporary strengthening of the response at the start of extinction. Skinner (1938, p. 76), for example, noted that the rate of responding may temporarily increase after the onset of extinction. Likewise, Notterman and Mintz (1965) and Halasz (1963) reported an increase in the force of responding at the start of extinction, and Azrin, Hutchinson, and Hake (1966) reported the occurrence of aggressive responses at the onset of extinction. It is interesting to note that in all of these instances, the temporary increase in the strength of the response at the onset of extinction was most apparent after a history of continuous reinforcement.

In the present study, emotional responses generated by extinction appeared to be a more important factor than the absence of non-reinforced responding to S- in determining resistance to extinction. It might, however, be the case that if these emotional responses were eliminated, as for example, following the administration of certain tranquilizers (*cf.* Terrace, 1963a), the resistance to extinction of the response to S+ might be lowest following errorless discrimination training. Under these kinds of conditions, it might also be the case that errorless discrimination performance would remain intact throughout extinction.

EXPERIMENT II

In Exp. I, only the early-progressive group, trained under the trial procedure did not have a history of non-reinforced responding before extinction. All of the remaining groups, however, emitted non-reinforced responses to either S+ or to S- during discrimination training. It was hypothesized that discrimination performance during extinction was disrupted following early-progressive discrimination training under the trial procedure, in three out of three instances, because these subjects had not had a history of intermittent reinforcement for responding to S+ during discrimination training. Experiment II tested this hypothesis by gradually lowering the probability of reinforcement for responding to S+ from 1.0 to 0.10. Thus, unlike Exp. I, in which the probability of reinforcement on an S+ trial was abruptly reduced in going from discrimination training to extinction, in Exp. II the value of this probability was gradually reduced during discrimination training.

METHOD

Subjects

Three male White Carneaux pigeons (B-120, B-124, and B-125) with no experimental history were maintained at 80% of their free-feeding weights throughout the experiment.

Apparatus

The apparatus was identical to that used in Exp. I.

Procedure

Each subject was trained under the early-progressive discrimination procedure used in Exp. I. After the first five S+—S- sessions, during which the probability of reinforcement was 1.0, the probability of reinforcement was reduced as follows: two sessions of 0.75 probability of reinforcement; two sessions of 0.50; three sessions of 0.25; and three sessions in which the probability of reinforcement was 0.10. Each subject was then given 30 extinction sessions using the extinction procedure of Exp. I. It should be noted that in Exp. II, there was no alternation between S+ and S+—S- sessions as there was in Exp. I. In Exp. II, only the S+—S- and the extinction procedures were used.

RESULTS

None of the subjects responded to S- during the S+—S- sessions. The reduction of the probability of reinforcement for responding to S+, from 1.0 to 0.10, affected neither the probability of responding to S+ nor the latency of responding to S+.

After the key peck was conditioned during the first experimental session, the probability of responding to S+ was 1.0 for each subject during each of the 14 discrimination sessions. Thus, discrimination performance was perfect before extinction. The median latencies of the response to S+ during the last five S+—S- sessions of Subjects B-120, B-124, and B-125 were, respectively, 0.45, 0.73, and 0.68 sec. These medians are virtually indistinguishable from the median latency of responding to S+ of the subjects of the early-progressive group of Exp. I (*cf.* Terrace, 1963*b*, Fig. 6).

The cumulative number of responses of each subject to S+ and to S- is shown in Fig. 3. In each case, extinction had no effect on S- responding; none of the subjects responded to S- during any of the 30 extinction sessions.

Another difference in the extinction performance of the early-progressive groups in Exp. I and II can be seen in the resistance to extinction of the response to S+. In Exp. I,

Fig. 3. The cumulated number of responses to S+ and to S- of each of the subjects of Exp. II during 30 extinction sessions.

the average number of responses to S+ during extinction was 456. In Exp. II, the average number of responses emitted to S+ was 888. This difference was undoubtedly the result of the intermittent reinforcement of the response to S+, rather than the 10 additional extinction sessions that the early-progressive group of Exp. II received. Inspection of Fig. 3 shows that responding to S+ had essentially ceased by the end of the twentieth extinction session, the point at which extinction was terminated in Exp. I.

DISCUSSION

Experiment II demonstrated that errorless discrimination performance under a trial procedure could be maintained throughout extinction if the response to S+ had a history of intermittent reinforcement during discrimination training. In the Discussion of Exp. I, it was noted that a reasonable explanation of the maintenance of errorless performance during extinction in the case of the free operant group was the development of frustration tolerance by the intermittent reinforcement of responding to S+ during discrimination training. Presumably, the high level of frustration tolerance in Exp. II was also the result of the intermittent reinforcement of responding to S+ during discrimination training.

Another important implication of the results of both Exp. I and II is that errorless discrimination learning is not an unmixed blessing if the response to S+ is continuously reinforced. To ensure that errorless performance continues during extinction, it is necessary to reinforce intermittently responding to S+ during discrimination training.

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