Frustrative nonrelief in instrumental escape conditioning

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The generality of the frustration effect in an aversive stimulus conditioning procedure was examined by training and testing 40 rats in a double cold-waterway escape conditioning apparatus. Experimental and control procedures analogous to appetitive conditioning experiments (e.g., Amsel & Roussel, 1952; Wagner, 1959) indicated that frustrative nonrelief (i.e., reinforcement omission) in the first goal tank yielded significant increments in swimming speed in the second waterway, and that these increments in performance were dependent upon initial training with continuous relief (i.e., reinforcement) in the first goal tank. Extensions of the generality of the frustration effect are discussed.

Amsel (1951, 1958) has described a conceptualization of the effects of nonreinforcement that, under certain conditions, imputes active motivational properties to nonreinforcement in appetitive conditioning situations. Briefly, the theory hypothesizes that after an instrumental response has been reinforced a sufficient number of times to permit the development of anticipatory goal responses, nonreinforcement will elicit a primary motivational condition termed "frustration" (R_F). One of the predicted behavioral consequences of this reaction is an immediate increase in response vigor. This hypothesis was confirmed in a series of double-alley appetitive conditioning experiments by Amsel and his associates (for a review, see Amsel, 1958). The present study investigates the effects of analogous operations in an escape conditioning paradigm, and is one of a series concerned with the generality of learning phenomena.

Behavioral similarities between reward training and escape conditioning have been reported for basic manipulations of drive-stimulus intensity and reinforcement magnitude (see, for example, Campbell & Kraeling, 1953; McAllister & McAllister, 1967; McAllister, McAllister, Brooks, & Goldman, 1972; Woods, 1967, 1973; Woods, Davidson, & Peters, 1964; Woods & Feldman, 1966). Yet such generality has not always been obtained. Major differences in the effects of partial reinforcement in escape conditioning as compared to reward training, for example, have been reported by Woods, Markman, Lynch, and Stokely (1972). This work documented findings which may, at least partially, account for such discrepancies, viz, the more disruptive effects of the failure to administer "relief" (i.e., reinforcement) in the escape paradigm. "Nonrelief" (i.e., nonreinforcement) therefore, appears to be a powerful variable and its study in the double-alley adapted to escape conditioning is a logical step.

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Two reports have already described escape conditioning analogs of the appetitive double-alley experiment. Lambert and Hammond (1970) replicated the basic Amsel and Roussel (1952) experiments including additional control procedures (Wagner, 1959) using a shock-escape procedure. Their results showed a "reversed frustration effect," i.e., the rat subjects ran *slower* after frustrative nonrelief (reinforcement omission) than after relief from shock. Whether these results are typical of all aversive stimuli or whether they are due to the peculiarities of electric shock remains an empirical question. Another report by Graham and Longstreth (1970) described a double-alley shock-escape procedure that differed in possibly important aspects. First of all, they used a within-subjects design, and secondly, distinctive cues in Goalbox 1 signaled relief or nonrelief conditions. They did not find any differences in second-alley speeds, but they did find significantly shorter first-goalbox-departure latencies following nonrelief than following relief. This latter finding was interpreted by them as evidence for a frustration effect.

The purpose of the present study was to add to our relatively sparse information on the effects of frustrative nonrelief as operationally defined by Amsel (1958). Since Amsel considered the effect to be dependent upon the amount of previous experience with continuous reinforcement, we have included experimental groups with differential amounts of continuous relief experience: specifically, 12, 24, and 48 trials. We also included a control group tested on a 50% schedule without any prior continuous relief experience, and a control group, following Wagner (1959), that never had any relief experience whatsoever.

METHOD

Subjects

Naive male BHE descendents ($N = 40$) were obtained in two shipments from Flow Research, Inc., Dublin, Virginia. The subjects weighed approximately 250 g at the beginning of the study. Water and food were freely available in each rat's home cage throughout the experiment.

Apparatus

A prototype cold-water single waterway has been fully described by Woods (1964). The present apparatus incorporates elements of this design, with major modifications, in the construction of an in-line double waterway for the study of cold-water escape conditioning. Briefly, it consisted of two 158-cm waterways of 16 cm width and 30 cm (water) depth. The middle goal (Goal Tank 1) and the end goal (Goal Tank 2) were 36 x 16 x 10 cm. Both goal tanks were fitted with pneumatically operated opaque Plexiglas doors allowing direct entry from waterway to goal tank without handling by the experimenter.

Water temperature in the waterways defined the degree of aversiveness or drive-stimulus intensity; the temperature differential between the waterway and the goal tank specified the magnitude of relief. The water circulated through reservoirs that maintained the temperature within $\pm 1.0^\circ\text{C}$ by presetting Bronwill constant-temperature circulators operating in conjunction with a Forma scientific refrigerated bath. It was possible to supply Goal Tank 1 by either one of two reservoirs so that a change from a condition of relief to one of nonrelief could be accomplished in less than 2 min. To change the goal-tank condition, the supply from one reservoir was diverted into a shunt system, the goal tank was drained into that reservoir, and then the other reservoir was shifted to a supply function. These changes were all facilitated by a system of solenoid-operated valves.

Underwater photobeams 92 cm apart and 33 cm from each end of the waterways were used to control clocks equipped with reciprocal faces enabling the direct reading of speed scores (10/sec). Experimenter manually started the first clock as subject was lowered into each waterway, while the second started when the first photobeam was interrupted. Both clocks stopped when the second photobeams were interrupted. Goal-tank detection periods and intertrial intervals were timed with a standard stopwatch.

Between trials, subjects were housed in a translucent Plexiglas detention cage maintained at approximately 34°C by forced-air electric heaters.

Design

The design of this experiment is similar to that described by Amsel and Roussel (1952) and Wagner (1959) and consisted of an initial training period followed by testing. The experimental groups (hereafter referred to as FE groups) were trained for 48 trials, 24 trials, or 12 trials with continuous relief in Goal Tank 1. The 0% control group was trained for 48 trials with relief never given in Goal Tank 1 (Wagner, 1959). To assess the importance of continuous relief preceding testing, a second control group was trained for 48 trials on a 50% schedule of partial relief in Goal Tank 1. In testing, all groups (except the 0% control) received 50% relief in Goal Tank 1. All groups received continuous relief in Goal Tank 2 throughout this study.

This design was initially executed with four subjects in each group and then completely replicated, resulting in a total of eight subjects per group.

Procedure

The temperatures of the waterways were maintained at 20°C for all groups in training and testing. Based on previous psychophysical scaling of this aversive dimension, it is known that this temperature is moderately aversive; after submerging their hands for 30 sec, most human subjects described water of this temperature as cool and uncomfortable (Woods, Griffith, Page, & Rodier, 1967). On relief trials, subjects escaped to a goal tank maintained at 40°C , i.e., a temperature increment or relief magnitude of 20°C ; on nonrelief trials, subjects escaped to a goal tank containing water the same temperature as the waterway.

Commencement of training for each group was determined by the number of trials received before testing. Thus, groups receiving 48 training trials started on Day 1 and received four trials per day for 12 days. Groups receiving -24 and -12 training trials started on Day 7 and Day 10, respectively. Testing began on Day 13 and consisted of four trials per day for 6 days. For the FE groups and the 50% control group, the sequence of relief (R) and nonrelief (N) trials was (after Wagner, 1959): RNRN, RNRN, RNRN, RNRN, RNRN, RNRN.

The experimenter ran four subjects at a time in each condition. Within each group, the subjects were treated in sequence so that each received the first trial before the first subject received the second trial, etc. For a trial, the subject was removed from the detention cage and gently lowered into the starting end of Waterway 1; when he reached the far end, the pneumatically controlled doors were actuated by experimenter, allowing the subject to enter Goal Tank 1 without delay. After 30 sec, subject was removed and the procedure was immediately repeated in Waterway 2. After 30 sec in Goal Tank 2, the subject was removed to the detention cage. The intertrial interval was approximately 6 min, which was the time necessary to run the other three subjects and make changes in Goal Tank 1 temperature from relief conditions to nonrelief conditions or vice versa in accordance with the schedule.

For each waterway, experimenter recorded the overall time from initial immersion to interruption of the final photobeam, the swimming speed in the 92-cm midsection, and additionally noted whether the subject had traversed the midsection without commission of competing responses (e.g., stopping, reversing, clawing at waterway wall, etc.). Thus, these procedures yielded an overall speed score, a measure of swimming speed, per se, and an indication of competing response activity in each waterway.

RESULTS

Establishment of the frustration effect in this escape conditioning procedure was contingent upon demonstrating an increase in response speed in Waterway 2 following nonrelief in Goal Tank 1. Thus, the data of prime interest are the measures of performance in Waterway 2 during testing.

Waterway 2—Testing

Figures 1 and 2 show the mean total or overall response speeds and swimming speeds (i.e., speed in the absence of competing responses) for each group in Waterway 2 following relief and nonrelief in Goal Tank 1. Note that in all cases for the FE conditions, the speeds following nonrelief are faster than the speeds following relief.

For the statistical analyses, difference scores (D) were computed for all FE subjects and for subjects in the 50% control group by subtracting the mean measure of performance in Waterway 2 following relief in Goal Tank 1 from the mean measure following nonrelief. Thus, a positive D score indicates that performance following nonrelief was superior to that following relief. Similar calculations were computed for subjects in the 0% control group by subtracting the mean of trials numerically corresponding to relief trials for experimental subjects from the mean of trials corresponding to nonrelief trials. Table 1 presents the

Figure 1. Waterway 2 total response speeds following relief and nonrelief trials in Goal Tank 1 during testing phase. Numbers on the FE groups indicate the number of training trials. (Note: The 0% control group never received any relief trials. The trials plotted for this group are the same numerically as the relief trials for the other groups.)

performance measures, the derived D scores, and the t values (correlated observations). As can be seen, both total response speeds and swimming speeds are significantly greater in the FE groups following nonrelief trials. It is of interest to note that this difference in total speed was obtained with each of the 24 subjects, and the difference in swimming speed was obtained with 23 of the 24 subjects in the FE groups. Development of the frustration effect was similar for the three FE groups, and the data were combined for the block-by-block curves in Figure 3. No significant differences were found with these measures for the 50% control group or the 0% control group. Noncompeting response trial frequency was high under all conditions and no significant differences were found.

It will be recalled that the 50% control group was included to assess the effect of experience with nonrelief during training on the frustration effect. Since this group had 48 training trials, it is appropriate to compare it with the FE group which also had 48 trials. For the latter group, the D scores were significantly greater than zero; also an analysis of variance on the D scores for these two groups yielded a significant F for Ds based on total speed ($F = 9.43$, $df = 1/13$, $p < .05$). That is, a frustration effect occurred only in the group which had experienced nonrelief in training.¹ Similar comparisons for swimming speed and frequency of noncompeting response trials were not significant ($F_s < 1$).

The control group which never experience relief in Goal Tank 1 (the 0% control group) was included to

ascertain whether the frustration effect was due to enhanced performance following nonrelief or due to depressed performance following relief. To determine which of these alternatives seems to be accounting for the results, we compared trials following *relief* in testing the FE group having 48 training trials with the numerically corresponding trials of the 0% control group. These trials were not significantly different for total speed measures ($t = 1.32$, $df = 14$, $p > .05$) nor for swimming-speed measures ($t = 1.02$, $df = 14$, $p > .05$). But when trials following *nonrelief* in the FE group are compared with numerically corresponding nonrelief trials in the 0% control group, it was found that the FE group was significantly faster on total speed ($t = 2.61$, $df = 14$, $p < .05$) and on swimming speed ($t = 2.55$, $df = 14$, $p < .05$). Hence, it appears to indeed be a frustration effect. The difference during testing in the FE group is interpreted as being due to an *enhanced performance following nonrelief* rather than a depressed performance following relief.

Group 50%-48

This group was included in the experiment to assess the possible development of the frustration effect in subjects following extended training under partial reinforcement conditions and no previous continuous reinforcement. Independent analysis of three response measures was by the Treatments by Treatments by Subjects design (Lindquist, 1953, p. 237) with Goal Tank 1 conditions and trial blocks as the two main treatment effects. In that training and testing were undifferentiated for this group, the total of 18 trial blocks were included in the analysis.

Figure 2. Waterway 2 swimming speeds following relief and nonrelief trials in Goal Tank 1 during testing phase. (see note in Figure 1 caption.)

Table 1
Mean Performance Measures in Waterway 2 Following Nonrelief (N) and Relief (R) in Goal Tank 1

FE Groups	Total Speed (ms^{-1})				Performance Measure Swimming Speed (ms^{-1})				Frequency of Noncompeting Response Trials			
	N	R	$\bar{D}$	t	N	R	$\bar{D}$	t	N	R	$\bar{D}$	t
100%-12	.332	.303	.029	2.66*	.389	.371	.018	2.64*	.95	.88	.07	1.00
100%-24	.327	.296	.031	3.31*	.385	.364	.021	3.27*	.93	.88	.05	1.00
100%-48	.305	.278	.027	4.62*	.376	.349	.027	3.72*	.95	.95	.00	0
Control Groups												
50%-48	.280	.273	.007	1.16	.334	.323	.011	1.16	.88	.90	-.02	1.00
0%-48†	.225	.236	-.011	-1.20	.326	.331	-.005	-.63	.74	.76	-.02	.95

†Means for N and R trials were computed for trials numerically corresponding to N and R trials for FE groups.

* $p < .05$

Inspection of the data for this group indicated slight increments in performance following nonrelief, relative to performance following relief (total speed: $\bar{D} = .009$; swimming speed: $\bar{D} = .005$; noncompeting response trial frequency: $\bar{D} = .01$). However, these differences were not found to be significant ($ps > .05$). Significant F ratios for trial blocks effects in the analysis of swimming speeds ($F = 2.94$, $df = 17/119$, $p < .05$) and noncompeting response trial frequencies ($F = 3.42$, $df = 17/119$, $p < .05$) reflected the observed decrements in swimming speeds over the 18 trial blocks and an initial increment in noncompeting response trial frequencies.

Thus the statistical analyses failed to confirm the development of the frustration effect in this escape conditioning procedure without the initial training experience of continuous relief in Goal Tank 1.

DISCUSSION

The results of this experiment clearly confirm the generality of the frustration effect in this escape-conditioning analog of the double-alley reward-training experiment. The differences in total and midsection speeds as a function of Goal Tank 1 condition following training with continuous reinforcement were consistent with reports of appetitive conditioning procedures described by Amsel and Roussel (1952). Additionally, these results are consistent with the shock-escape experiment described by Graham and Longstreth (1970) but inconsistent with the "reversed frustration effect" reported by Lambert (Lambert, 1970; Lambert & Hammond, 1970, Experiment I).

The results additionally indicate that the number of trials in training selected in this experiment affect the magnitude of the frustration effect nonsignificantly, though a moderate trend was consistent with the report of a positive relation between number of trials in training and the magnitude of the effect in the reward-training procedure (Yelen, 1969).

Selected comparisons between the FE group that received 48 trials in training and a control group indicated that total and midsection speeds in Waterway 2 during testing were a function of speed increments following nonreinforcement rather than an artifact of speed decrements following reinforcement; thus, these data were consistent with the reports of Wagner (1959) and Graham and Longstreth (1970).

Previous double-alley appetitive conditioning experiments (Amsel & Hancock, 1957; Wagner, 1959) and one double-alley shock-escape experiment (Lambert & Hammond, 1970, Experiment II) have included the control group that received 50% relief in the first goal from the outset of training. These results indicated that a frustration-like effect typically appeared only after approximately 20 trials of training, indicating the dependence of this effect upon associative factors.

Figure 3. Block-by-block Waterway 2 total speeds for the FE groups (combined) on N and R trials.

Analyses of the performance of Group 50%-48 in this experiment suggested that differential performance in Waterway 2 as a function of Goal Tank 1 condition did not appear significantly during the course of 72 trials. Although not confirming previous findings per se, it does indicate that the frustration effect in Waterway 2 in this escape conditioning procedure is particularly sensitive to the initial training of continuous relief.

An alternative interpretation of the effects of nonreinforcement has been described by Staddon (1970) and Kello (1972). An observed increment in free-operant performance following the omission of reinforcement was attributed to the "discriminative" and "inhibitory" effects of reinforcement rather than to the "frustrative" and "energizing" effects of nonreinforcement. The relevance of this cogent interpretation to the present data is limited, for the degree of similarity between discrete-trials double-alley experiments and ostensible free-operant analogs is presently indeterminable. For instance, it is not yet clear what type of schedule of reinforcement is the appropriate analog of an alleyway. Similarly, the one-key/bar procedure (the usual choice of researchers) results in different response patterns than a two-key/bar procedure (the usual choice of researchers) results in different response patterns than a two-key/bar procedure (Hughes & Dachowski, 1973). Research programs have examined such questions (Donahoe, 1970; Platt, 1971) yet the limited information precludes the unequivocal use of free-operant analogs of the discrete-trial double-alley experiment.

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NOTE

1. Further support for this conclusion comes from more detailed analyses of the performance of the 50% group throughout the total 18 blocks of trials in this study. The results of these analyses indicated that the condition of Goal Tank 1 had no significant effect on performance and that the Trial Block by Goal Tank 1 Condition interactions were not significant.

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