The role of reinforcement and nonreinforcement in an operant frustration effect*

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Male albino rats were run in a discrete-trial two-bar operant analog of the double alley. Completion of a FR 4 response chain on the first bar was rewarded 50% of the time for the 12 experimental Ss, but was never rewarded for the 12 control Ss. Both groups received consistent reward at the end of a FR 4 chain on the second bar. Eighty-four trials were given at a rate of four trials per day. A significantly faster rate of responding on the second bar was found following nonrewarded first-bar ratios than following rewarded first-bar ratios. This frustration effect was not attributable to response depression, since the nonrewarded performance of the experimental group exceeded that of the control group.

Increased vigor of response following a nonreward (N) as compared to that following a reward (R) when an expectancy of reward is present has been termed the frustration effect (FE). Most of the evidence concerning the FE has come from studies employing the double runway (e.g., Amsel & Roussel, 1952; Wagner, 1959). The increased vigor of responding following N has been attributed to emotional effects which act to increase the level of motivation (Marzocco, 1951). Such an interpretation has been expanded to account for a number of phenomena associated with partial reinforcement (Amsel, 1958, 1962; Spence, 1960).

Wagner (1959) used a control group which allowed for the assessment of the relative contribution to the FE of response depression resulting from reward and of response increase resulting from frustrative nonreward. The second-runway performance of a control group which was never rewarded in the first goalbox was compared to the nonrewarded performance of the experimental group which received 50% reward in the first goalbox. If the second-runway performance following N for the experimental group is superior to the second-runway performance of the control group, the difference may be attributed to frustrative nonreward.

Considerable effort has been directed toward the development of an operant analog of the discrete-trial double-runway situation (Davenport & Thompson, 1965; Staddon & Innis, 1966; Davenport, Flaherty, & Dyrud, 1966; Carlson, 1968). A number of such studies

have shown shorter latencies and/or higher response rates following N as compared to responding following R. Only three studies, however, have included control procedures analogous to that used by Wagner (1959).

Hamm and Zimmerman (1967), in an effort to provide such control data, trained pigeons on a four-component multiple-chained schedule in a single-keyed operant chamber. The first two components corresponded to the double-runway FE situation in which reward was initially given at the end of both components and later omitted at the end of the first component on one-fourth of the occasions. In the last two components, the Ss were never rewarded at the end of the third component but were always rewarded at the end of the fourth component. Using this within-S control procedure, performance in Component 2 following N in Component 1 was found to be more vigorous than performance in Component 2 following R. However, the N-trial Component 2 performance was no more vigorous than the performance in Component 4; thus, the results could not be interpreted in terms of frustration.

In the second study (Platt & Senkowski, 1970), three groups of hooded rats received 100% reward at the end of the second component but 0%, 50%, or 100% reward at the termination of the first component. Both components consisted of a FR 8 response chain. The apparatus was an operant chamber with a single retractable lever. During pretraining, all Ss received reinforcement for pressing the lever. The second-ratio performance of the 50% group was greater following N at the end of the first ratio than that following R, but the second-ratio performance of the 0% group exceeded the performance of the 50% group following N. Thus, reinforcement-induced demotivation could account for the second-ratio performance of the 50% group.

The third study employing a Wagner control group (Cole & Van Fleet, 1970) used only three Ss per group and involved two experiments. The performance of the 0% group, relative to the performance following N for

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the 50% group, was not reliable in the two experiments.

The present study employed an experimental group which received 50% reward on the first bar of a double-bar operant chamber throughout the experiment. The 0% control group was trained by a procedure that omitted shaping on the first (never-rewarded) bar. Response measures were taken at three different points in a FR 4 response chain. An analogous procedure has been useful in determining direction or progression of effects in runway situations (Goodrich, 1959).

METHOD

Subjects

The Ss were 30 male Sprague-Dawley rats purchased from the Dan Rolfmeyer Co., Madison, Wisconsin. All Ss were approximately 95 days old and had mean body weights of 235 g (SD = 15.41) at the beginning of acquisition. The animals were housed in individual cages and kept on a reversed light-dark cycle. All Ss were maintained on a 22½-h deprivation schedule (approximately 80% ad lib body weight). At the beginning of acquisition, pairs of Ss were matched on the basis of percent ad lib body weight and latency of responding in magazine training. One S from each of the pairs was randomly assigned to one of the two groups.

Apparatus

The apparatus consisted of an operant conditioning chamber with two retractable bars purchased from Foringer Co., Rockville, Maryland. Each bar required a static pressure of 41 g to initiate a switch closure. The chamber was 23 cm wide, 36 cm long, and 29 cm deep. A panel at one end of the chamber contained three independently operable stimulus lights. One of the stimulus lights was located above the foodcup. The other two stimulus lights were located above the bars. The foodcup was located between the bars. A pellet dispenser provided reinforcement which consisted of three 45-mg Noyes pellets in both goal situations. Audio masking was provided by white noise, and the apparatus was contained in a lightproof and relatively sound-resistant enclosure which was well ventilated. Chamber illumination was provided continuously by a 7-W fluorescent bulb located behind the stimulus panel. A one-way mirror in the top of the enclosure enabled E to observe S's behavior. Sodeco printing impulse counters (1/20-sec resolution) and accompanying electromechanical equipment were located in an adjacent room and were used to program sequences of events and record the data. Three latency measures were taken for each bar. The first time interval (start time) was measured from the introduction of the bar to the first barpress. The midchain interval was measured from the first barpress to the third barpress. The last time interval (goal time) was measured from the third barpress to the fourth barpress, which then terminated the bar presentation.

Procedure

Preliminary Training

On the first day of pretraining, each S was given 20 Noyes 45-mg reward pellets in a jar lid in its home cage. Two sessions of magazine training were given on each of the following 3 days. On the first day of magazine training, each S was placed in the experimental chamber with both bars in a retracted position and all stimulus lights off. The audio masking was present, and the foodcup contained 20 45-mg pellets. Each S remained in the chamber until all food pellets had been eaten. On the second day

of magazine training, all conditions were the same except that only 5 pellets were present in the foodcup. The remaining 15 pellets were delivered via the delivery mechanism when S approached the foodcup. Each pellet delivery was accompanied by a 1.5-sec tone from a 1,000-Hz tone source. On the final day, no food pellets were available initially and all of the 20 pellets and tone presentations were delivered when S approached the foodcup.

Experimental Training

During training, a daily session began with the placement of S in the experimental chamber facing away from the stimulus panel. After 15 sec, the first bar protracted. Immediately after the fourth barpress, the bar retracted and, depending upon the reinforcement schedule, three pellets were or were not delivered (G1). The 1,000-Hz tone of 1.5 sec duration was delivered regardless of the reinforcement condition. After 15 sec, the second bar protracted and the stimulus light above it was turned on. For half the Ss, the first bar was always on the left, and for the other half of the Ss, the first bar was always on the right. Immediately following the fourth barpress, the second bar retracted and the stimulus light over the foodcup was lit. At this time, three pellets and the tone were presented (G2). Fifteen seconds after the retraction of the second bar, the sequence was repeated. After two such sequences on the first 2 days and thereafter four per day for a total of 22 days, each S was removed from the apparatus and replaced in its home cage. No shaping of barpressing behavior was given for any S. When Ss failed to complete four barpresses on either bar within a 5-min period, the bar retracted and the appropriate goal situation took place. If eight such goal "placements" were required by any S on 2 consecutive days, the S was discarded from the experiment. Three Ss from the 0% group exceeded this criterion, and they, along with the matched experimental Ss, were discarded from the study, leaving 24 Ss.

Two schedules of reinforcement were used in the first goal situation. Ss in the 0% group never received a reward in the first goal situation. The 50% Ss received rewards and nonrewards in the first goal situation in one of the following orders for each block of four trials: RNNR, NRRN, NRRR, RRRN. These four orders were randomly permuted every four blocks for each 50% S. All Ss received 100% reward in the second goal situation.

RESULTS

Barpress latencies were transformed to reciprocals, and the three rates, start, midchain, and goal, were analyzed separately for each bar. Analyses of variance were performed on the first-bar data from both the 50% and 0% groups. Analysis of the three response measures indicated that the performance of the 50% group was significantly greater than the performance of the 0% group for all measures, as indicated in Fig. 1. The difference was significant beyond the .01 level ($F = 11.86, 13.50, 10.13$; $df = 1, 22$) for the start, midchain, and goal measures, respectively. Figure 2 shows midchain performance for both groups over days. The increase in performance over days was also significant beyond the .01 level ($F = 3.83, 2.02$; $df = 20, 440$) for the midchain and goal measures. The only other variable that was significant for first-bar performance was trials within daily sessions. The main effect of trials within daily sessions was significant beyond the .025 level for start and goal measures ($F = 3.21, 3.87$; $df = 3, 66$) and

was only marginally significant for the midchain measure ($F = 2.69$; $df = 3,66$; $p = .052$), reflecting a high response rate on the first trial of each day when compared to the performance on remaining trials for that day.

Analyses of variance were also performed on the second-bar data from the experimental group. The analysis of start rates revealed a significant effect of days ($F = 1.88$; $df = 20,220$; $p < .25$) and a significant difference between performance following G1 reward and G1 nonreward ($F = 6.68$; $df = 1,11$; $p < .05$). Inspection of Fig. 3 also reveals that the 0% group performed at a slightly higher rate than the experimental group following N in the start rates. The high start rate of the 0% group can be attributed to the development of a differential orientation response early in training. It was noted that the 0% Ss developed a habit of not visiting the foodcup following Bar 1, but instead oriented in front of the second bar. Further support for this interpretation is derived from the fact that only the start measure for Bar 2 fails to show inferior performance for the 0% group.

An analysis of the midchain response rates yielded a significant FE ($F = 9.37$; $df = 1,11$; $p < .025$) and a significant main effect of days ($F = 4.69$; $df = 20,220$; $p < .01$). Figure 4 shows the performance of the experimental and control groups on the midchain response measure. The rate of responding for the experimental group was greater following G1 nonreward than following G1 reward, and the 0% group's performance was approximately at the same level as the performance of the experimental group following G1 reward.

Fig. 1. First-bar performance as a function of response measure taken for both 50% and 0% groups. The solid line represents the 50% group's performance and the dashed line the 0% group's performance.

Fig. 2. First-bar midchain performance for the 50% and 0% groups over days. The solid line represents the performance of the 50% group and the dashed line the 0% group's performance.

Fig. 3. Second-bar performance as a function of response measure taken for both 50% and 0% groups. The open circles represent the 50% group's performance following first-ratio nonreward and the closed circles the 50% group's performance following first-ratio reward. The open triangles represent the performance of the 0% control group.

The goal rates of the experimental and control groups were very similar to the midchain rates, except reduced in magnitude. No significant effects were found for the goal measure, and no other main effects or interactions were significant for the start and midchain rates.

DISCUSSION

Evidence was obtained in an operant situation for a FE which is attributable to frustrative nonreward. The present study, then, differs from previous operant analogs of the FE in that the 0% group performance is inferior to that of the 50% group following both

Fig. 4. Second-bar midchain performance as a function of first-ratio reward and nonreward for the 50% and 0% groups over days. The open circles represent the 50% group's performance following first-ratio nonreward and the closed circles the 50% group's performance following first-ratio reward. The open triangles represent the performance of the 0% control group.

nonrewarded and rewarded first-bar ratios. There are at least two plausible explanations for the differences of the present results from those of previous studies.

First, most of the previous studies used a single manipulandum. By using two manipulanda, as in the present study, the magnitude of generalization of incentive from the second bar to the first should be diminished. Evidence for the independence of the first-bar performance can be seen by comparing the performance of the 0% group on Bar 1 to their performance on Bar 2. First-bar performance, which was never rewarded, is well below the consistently rewarded second-bar performance for the 0% group. These results indicate clearly that 0% Ss discriminated between first-bar and second-bar responding. Platt and Senkowski (1970) provide no direct evidence in their Experiment I to indicate discrimination between first and second ratios by 0% Ss. It might also be noted that the 0% group's performance on Bar 2 (100% reinforcement) is at approximately the same level as that of the 50% group on Bar 1 (50% reinforcement). This finding is in agreement with most of the instrumental conditioning literature, which generally reports 50% performance antecedent to the goal equal, or superior, to 100% performance.

A second difference between the present study and the previous analogs was in the method of training the 0% group to press a bar. In the present study, the Ss in the 0% group were never given a reward after pressing the first bar. In previous studies, a shaping procedure involved giving a reward for pressing the same bar or key that was later used for the nonrewarded ratio. Nonreinforcement following a history of reinforcement could have led to elevated performance on the part of the 0% groups.

Numerous other differences between the present procedure and previous studies (e.g., Platt & Senkowski, 1970) make it difficult to assign reasons for differences in results.

Several procedural variables are important, especially for the 0% group, if no shaping is to be given. In pilot work for this study, three important variables appeared to be age of Ss, length of FR requirement, and length of the midtrial interval. Approximately half of the Ss failed to learn if they were more than 150 days old, or if a FR 8 schedule was used, or if a 30-sec midtrial interval was used. Another pretraining variable which probably played a critical role in the conditioning was the pairing of a tone with food delivery. This procedure facilitated the conditioning process by insuring that the Ss would, in early training, visit the foodcup immediately after the behavioral sequence that was to be reinforced.

When the 0% group performance is inferior to the 50% group performance, as with midchain and goal measures in the present study, the increased performance following first-ratio nonreward for the 50% group is most easily interpreted as being due to the effects of frustrative nonreward, not demotivation. The present study, therefore, provides empirical support for the application of Amsel's frustration theory to discrete-trial operant situations and suggests that certain procedural details may govern the adequacy of the 0% control group as a control for the effects of demotivation.

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