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A TEST OF THE PARTIAL REINFORCEMENT EFFECT
''

A Thesis

Presented to

The Faculty of the Department of Psychology
The College of William and Mary in Virginia

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

by

Richard Dowell

1982

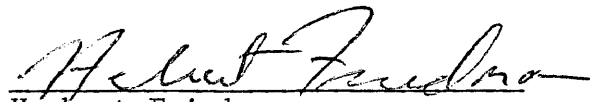
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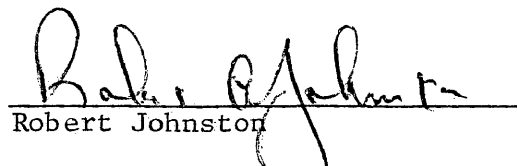
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Author

Approved, July 1982


Herbert Friedman


Robert Johnston


Larry Ventis

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ABSTRACT

The partial reinforcement effect (PRE), defined as the increased resistance to extinction exhibited by subjects receiving a partial reinforcement schedule, can be explained by the frustration and sequential aftereffects hypotheses which offer contradictory predictions concerning the minimum requirements for the PRE to be established. The sequential aftereffects hypothesis proposes that resistance to extinction is a function of N-R (N=nonreward, R=reward) transitions with a single N-R transition as the minimum criterion for establishment of a PRE. Alternatively the frustration hypothesis indicates that three trials of an R-N-R sequence are the minimum requirements for a PRE.

Three conditions of continuous (R-R), partial (N-R), and no (N-N) reinforcement were presented to two groups of albino rats. Following two training trials of an exploration response, the subjects were given ten minutes of extinction.

The continuous (R-R) condition was found to be consistently associated with a significantly greater number of responses during extinction followed in order by the partial (N-R) and control (N-N) conditions. This outcome is clearly contradictory to the prediction of the sequential aftereffects hypothesis and supported the frustration hypothesis. Furthermore, the resistance to extinction was found to be a linear function of the number of successive rewards received.

A TEST OF THE PARTIAL REINFORCEMENT EFFECT

INTRODUCTION

Investigations into the nature of nonreward and extinction have played a pivotal role in theories of learning. The increased resistance to extinction shown by subjects receiving partial reinforcement schedules, termed the partial reinforcement effect (PRE), has been the focus of much of this research. Explanations of the mechanisms responsible for this effect abound in the literature and play an integral part of any theory of learning. Currently the frustration hypothesis (Amsel, 1958) and the sequential aftereffects hypothesis (Capaldi, 1970) have generated the greatest interest concerning explanations of the PRE.

The frustration hypothesis proposes that a reward following a motor response serves to associate previously neutral stimuli to the response by classical conditioning. These stimuli, through repeated association with reward, become anticipatory in nature (conditioned stimuli) and act to direct ongoing behavior. In a similar manner, the association of these conditioned stimuli (s_g) with the moment-to-moment changes in behavior (r_g) become classically conditioned, setting up a motivation and directing mechanism for responses. This association has been termed anticipatory approach (r_g-s_g), and its effect is to create an expectancy of reward on

future trials. Anticipatory approach is strengthened through repeated rewards while nonreward is viewed as eliciting increasing frustration due to unmet expectations of reward. A rewarded motor response following this frustration causes frustration components (r_f-s_f) to be classically conditioned to the motor response. Eventually both anticipatory approach (r_g-s_g) and avoidance (r_f-s_f) become associated with the motor response due to the presence of reward on some trials.

Continuous reinforcement (CRF) represents a condition in which only rewarded trials are presented. The conditioning of anticipatory responses is, therefore, restricted to approach stimuli. Extinction following the establishment of anticipatory approach results in frustration and avoidance. Since avoidance stimuli have not been conditioned to the frustration response in the CRF subject, a decrement in responding (avoidance) occurs. In contrast, under conditions of partial reinforcement (PRF), both anticipatory approach and frustration are associated with the motor response due to the presence of both reward and nonreward as previously described. When presented with extinction conditions, PRF subjects continue to respond due to the prior association of anticipatory avoidance to the motor response, resulting in the typical PRE.

The foregoing account assumes that an initial reinforcer is necessary to condition anticipatory approach to the response and hence create expectation of reward on the following trial(s). Nonreward following this expectation results in frustration which may

become conditioned to the motor response on a subsequent rewarded trial. In summary, a single R-N-R (R=reinforced, N=nonreinforced) block of trials is the minimum requirement for establishment of the PRE.

The sequential aftereffects hypothesis (Capaldi, 1970) attempts to explain the PRE as a function of the order of rewarded (R) and nonrewarded (N) trials presented. Reward is viewed as producing an aftereffect (S^r) which persists to the following trial and is affected by the outcome on that trial. In a similar manner, nonreward produces an aftereffect (S^n) which is carried over and affected by the next trial. This aftereffect may include, but is not restricted to frustration. Reward serves a second function of strengthening the association between the aftereffects (S^r or S^n) and the rewarded motor response. Continuous reinforcement conditions, therefore, result exclusively in the association of S^r to the motor response (since S^n is not present). Partial reinforcement conditions produce both S^r and S^n aftereffects as a function of the presence of reward and nonreward, respectively. Reward following S^n results in the association of S^n to the motor response. An extinction procedure introduces only nonrewarded trials, therefore only the S^n aftereffect is present. Since continuously reinforced subjects have not formed an association between S^n and the motor response, their rate of responding decreases with exposure to an extinction procedure. Alternatively, the presence of associations between S^n and the motor response in partially reinforced subjects result in a greater resistance to extinction. Within this

orientation, the PRE is conceived of as a function of the conditioning of S^n to the motor response which only occurs in N-R transitions. The minimum requirement for producing a PRE is, therefore, a single N-R transition.

These two major theories have proven equally applicable to explaining the PRE following repeated acquisition trials. They do, however, provide conflicting predictions of the minimum number of acquisition trials for the PRE to be established. The sequential aftereffects hypothesis (Capaldi, 1970) proposes that resistance to extinction is a function of N-R transitions with a single transition as the minimum requirement for the PRE. The frustration hypothesis (Amsel, 1958), on the other hand, implies that three trials in an R-N-R sequence are necessary for the establishment of a PRE. Notice that only the sequential aftereffects hypothesis would predict a PRE after only two trials. With the introduction of a third trial, resulting in the sequence R-N-R, both theories provide a prediction of a PRE. This three trial sequence meets the requirements of following frustration with reward and an N-R transition as demanded by the frustration and sequential aftereffects hypotheses, respectively.

The competing predictions of the minimum number of trials for the establishment of a PRE have stimulated research in this area. Probably the most compelling research in support of the sequential aftereffects hypothesis has been conducted by McCain (1966) utilizing limited acquisition training. While procedures varied across McCain's series of experiments, the general procedure

involved introducing subjects into a straight alley runway with the two acquisition conditions consisting of continuous (R-R) or partial (N-R) reinforcement. The experiments indicated faster running speeds during extinction for partially reinforced subjects which McCain concluded to be in support of the sequential aftereffects hypothesis. The absence of an initial reinforcer necessary for the establishment of expectancy is viewed as the most damaging observation against the frustration hypothesis. In a similar experiment Padilla (1967) obtained results substantiating those of McCain, utilizing four acquisition trials.

SurrIDGE, Rashotte, and Amsel (1967) conducted an experiment similar to that of McCain (1966) utilizing four acquisition trials of continuous (R-R-R-R), partial (N-R-N-R), and control (N-N-N-N) conditions. Their results failed to substantiate those of McCain (1966) as no difference between CRF and PRF conditions in resistance to extinction was obtained. These discrepant results were attributed to procedural differences in the two experiments. SurrIDGE, Rashotte, and Amsel (1967) eliminated the habituation period and handling was not associated with feeding as in McCain's (1966) research. They concluded that habituation may have resulted in the build-up of anticipatory approach responses (r_g), thus McCain's (1966) initial N trial could result in frustration. Brooks (1969) observed that prior R goalbox placements resulted in more frustration than N prior placements as measured by a hurdle-jumping response. This observation suggests that anticipatory approach may be created during pre-experimental training and may

affect later conditions. In support of this proposition, Godbout, Ziff, and Capaldi (1968) observed greater running speeds for subjects receiving prior R goalbox placements. Along similar lines, Padilla (1967) obtained differential running speeds for subjects receiving different magnitude reinforcers after only four acquisition trials. He concluded that since incentive motivation differed for subjects receiving different rewards, r_g may develop very early in training (after four trials).

Spear and Spitzner (1967) obtained a greater resistance to extinction for subjects receiving N goalbox placements prior to acquisition, with the number of placements correlating positively with resistance to extinction. In this experiment subjects receiving 24 N trials followed by 24 R trials exhibited more resistance to extinction than a group receiving 12 N trials followed by 24 trials. This result can be taken as evidence that anticipatory avoidance (r_f-s_f) can be established through repeated exploration by creating frustration. In support of this hypothesis, Collerain (1978) observed that the emotional reaction to frustration (N trials) is accompanied by an odor which initiates avoidance responses. The effect of this frustration odor was reportedly evident after only four trials. No such emotional reaction was observed after two trials. Amsel, Hug, and Surrige (1968) recognized the accumulation of evidence concerning the small trial PRE after a number of trials seemingly insufficient to condition anticipatory avoidance to the motor response. Analyzing this previous research, Amsel, et al. (1968) observed a consistent

factor -- in each small trial experiment, showing a PRE, extremely large or multiple reinforcers were employed. In response, they (Amsel, et al., 1968) proposed that while eating such large reinforcers, subjects tend to eat with interruptions. Hence an experiment involving a single trial of five reinforcers is construed to actually represent five trials. In a similar fashion the consumption of a large reinforcer is accomplished in several interrupted sequences with each sequence representing (within this scheme) a separate trial. This explanation therefore introduces conditions necessary for the build-up of significant approach-avoidance responses making a PRE possible with limited acquisition trials.

Though the preceding experiments were explained in terms of the frustration hypothesis and therefore were taken as support, these results are not inconsistent with the sequential aftereffects hypothesis. The results do, however, cast into doubt the results obtained by McCain (1966) on several issues. In all of the experiments presented by McCain (1966), subjects received either a large reward or multiple rewards, thus allowing alternative explanations (Amsel, et al., 1968) to remain viable. Furthermore the presence of habituation trials in many of McCain's (1966) experiments also introduces the possibility of N trials prior to acquisition. Feeding following these N trials may have set up conditions quite contrary to those reported by McCain (1966). An alternative explanation may be as follows:

McCain's Conditions

N-R
R-R

Interpretation of McCain's Conditions

R (associated with feeding) -- N,N,N... (habituation,
possibly with frustration) -- R (associated with feeding) -- N-R

-- R-R.

Thus the conditions as reported by McCain (1966) contain the necessary elements for the frustration hypothesis with an initial reinforcer followed by an unreinforced trial. Difficulties with habituation and handling tend to be associated with alley running experiments, and their eradication is difficult without introducing other possible confounding procedures.

The task of experimenters employing a small number of acquisition trials appears to be reducing the potential effect of extraneous variables associated with habituation and handling. At the same time responses requiring shaping are not practical since they introduce variable amounts of reinforcement which exceed the two trials required. The present research attempts to replicate the findings of McCain (1966) utilizing an exploration response. This response takes advantage of the unlearned exploratory behavior of rats, thus eliminating the necessity of shaping. The acquisition response is defined as the frequency with which a subject puts its head through (explores) an opening of an exploratory box with reinforcers present as conditions dictate. The experimental conditions (R-R, N-R) of McCain (1966) were retained since the critical differentiating factor between these major theories occurs at two trials. With the addition of a third trial to meet the requirements of the frustration hypothesis, both theories provide equivalent predictions of a PRE. In addition to the partial (N-R) and

continuous (R-R) conditions, a no reinforcement (N-N) group was included to control for the naturally occurring rate of exploratory behavior. Feeding was independent of handling, since handling was limited to the initial placement of subjects into the exploratory apparatus. Criticisms of previous research concerning multiple or large reinforcers was addressed through the use of a single high preferability reinforcer. Resistance to extinction, as measured by the number of cumulative responses following the two acquisition trials was recorded for ten minutes.

A greater resistance to extinction for the partial group (N-R) would provide support for the sequential aftereffects hypothesis since the critical N-R transition is present. The absence of an association between S^n and the motor response, for the continuously reinforced group (R-R), would result in a decreased tendency for them to respond. Given this interpretation, the sequential aftereffects model would predict that the conditions would be in the order N-R, R-R, N-N relative to resistance to extinction. The frustration hypothesis, being based upon the Hullian theory of learning, would predict no PRE for the partial (N-R) condition since the initial reinforced trial required to create expectancy is not present. Given that stimulus intensity and incentive motivation are held constant, and that drive should evidence minimal decrement with two reinforcers, habit strength should function as the primary determinant of responding. Within this (Hullian) framework, habit strength is viewed as the summation of successive reinforcements, therefore the continuous (R-R) condition would be predicted to

exhibit a greater tendency to respond due to the presence of an additional reinforcer. Furthermore the order of conditions with respect to resistance to extinction should be R-R, N-R, and N-N, with the strength of resistance being proportional to the amount of reward received.

METHOD

Subjects

Subjects were 78 albino rats (Sprague Dawley derived) of approximately 180 days of age. Due to subject availability, 39 males with no previous handling and 39 females with prior handling and Skinner box experience were used. The two groups of 39 were run separately, though the same procedure was followed in both cases. Subjects were randomly assigned to one of the three experimental conditions with thirteen subjects assigned to each condition (continuous, partial, control). One week prior to the introduction of experimental conditions, each subject was trained to eat the reinforcers. For male subjects, handling was limited to their placement into the exploratory chambers. A minimum criterion of two responses was required for inclusion into the experiment. Based on this criterion, seven control, two partial, and three continuous reinforcement subjects were dropped from the male group. No female subjects were eliminated as a result of this criterion.

Apparatus

The experimental apparatus consisted of a wooden box, 38 cm. x 24 cm. x 23.5 cm., with a wire mesh floor and top. Five exploratory chambers of the same dimensions were employed for the running of five subjects simultaneously. All sides were similar in

appearance with the exception of one end which contained a 4 cm. diameter opening. A free swinging (non-friction) door was located on the exterior thus separating the opening from the feeder trough. This door served the dual purpose of prohibiting subjects from seeing into the feeder trough while providing a distinct response for measurement. The movement of this door could only be accomplished by the subject pushing its head through the opening, as it was located 4 cm. above the floor. A silicon photo transistor (FPT 100, Archer Electronic Parts) was located on the floor of the feeder trough so that the door would cast a shadow on it if it were moved. A change in light intensity on the photo transistor was recorded on a polygraph and was designated as an "exploratory" response.

Prior experimentation (Dowell, note 1) has indicated that the standard 45 mg. Noyes pellet was not consistently located or consumed without altered prior training. In response, all subjects were trained to eat a preferred pre-sweetened breakfast cereal of uniform size (50 mg.) and shape (Trix, General Mills). This cereal and sugar pellet was employed as the reward on all reinforced acquisition trials. As a control for olfactory stimuli, a cereal pellet was fixed to the back of the feeder doors.

Procedure

Five randomly selected subjects were run at a time with each of the three conditions represented. All subjects were maintained on normal Purina laboratory chow diets with reinforcer consumption training occurring on days 1-7. On day 8 each subject was

exposed to 24 hours of deprivation in their home cages. Following deprivation each subject was placed in an exploratory chamber with reinforcers present as conditions (N-N, N-R, R-R) dictated.

Following the two acquisition trials, an extinction procedure was instituted for ten minutes. The number of exploratory responses, as measured by the event recorder, served as the experimental measure.

RESULTS

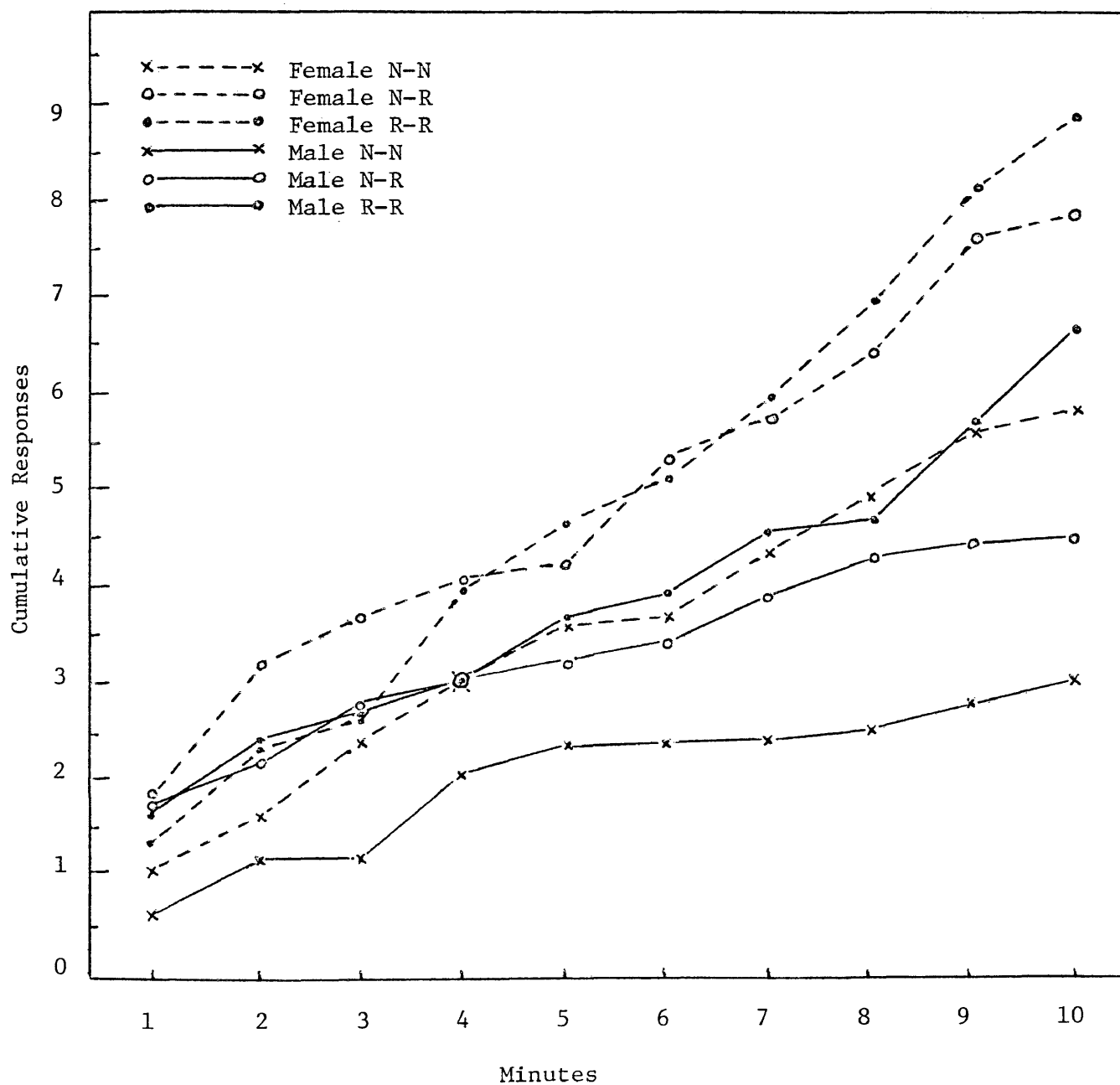
The continuous condition, for both the male and female groups, was associated with the greatest number of cumulative responses following ten minutes of extinction (see table 1). As shown in Figure 1, the continuous conditions reflected both a lower initial number of responses (minute 1) and a higher terminal number of responses (minutes 7-10), which taken together are indicative of a greater slope. This greater slope for the continuous condition is reflective of a greater resistance to extinction. Furthermore the order of conditions, in reference to the cumulative number of responses during the extinction period, remained consistent across both groups (sexes). The female subjects emitted a greater number of responses per condition, relative to the males (see table 1).

A three-way analysis of variance with sex by acquisition condition across the ten measurement periods was performed on the number of exploratory responses. This analysis indicated that the main effect of the acquisition conditions presented was significant ($F= 3.37$, $df= 2,60$; $p < .05$), with the continuous (R-R) condition being associated with the greatest resistance to extinction. The female group was also found to emit a significantly ($F= 8.12$, $df= 1,60$; $p < .01$) greater number of responses during

TABLE 1
CUMULATIVE RESPONSES FOLLOWING TEN MINUTES OF EXTINCTION

Group	Condition	Responses	SD
Male	N-N	3.00	.55
	N-R	4.35	.71
	R-R	6.60	1.15
Female	N-N	5.86	1.01
	N-R	7.85	1.21
	R-R	8.78	1.13

FIGURE 1
 CUMULATIVE NUMBER OF RESPONSES
 ACROSS TEN MINUTES OF EXTINCTION FOR ALL CONDITIONS



extinction compared to the male group. No significant interactions were found.

A secondary analysis was performed to estimate the relative impact of two versus a single reinforcer on responding. This ratio was computed (see table 2) by comparing the continuous (2 rewards) and partial (1 reward) conditions with the control (0 rewards) condition at the tenth minute of extinction. These values were weighted for the number of subjects per group and then averaged within the condition. The results indicate that the difference between a first and second reinforcer (continuous-partial) is roughly equivalent to the effect of a single reinforcer (partial-control).

TABLE 2
 RATIO OF CONTINUOUS AND PARTIAL GROUPS
 RELATIVE TO THE CONTROL GROUP AT TEN MINUTES

Ratio label	^a Computation	Ratio Value	Difference
Continuous	$\left[\left(\frac{8.78}{5.86} \right) (13) + \left(\frac{6.60}{3.00} \right) (10) \right] / 23 = 1.80$		
Partial	$\left[\left(\frac{7.85}{5.86} \right) (13) + \left(\frac{4.35}{3.00} \right) (11) \right] / 24 = 1.39$.41
Control	$\left[\left(\frac{5.86}{5.86} \right) (13) + \left(\frac{3.00}{3.00} \right) (6) \right] / 19 = 1.00$.39

^aValues enclosed in parentheses are the cumulative number of responses weighted for the number of subjects per group.

DISCUSSION

While the two major theories concerning the PRE have provided equally accurate explanations following repeated trials, they offer conflicting predictions as to the minimum requirements for the establishment of the PRE. The sequential aftereffects hypothesis (Capaldi, 1970) proposes that resistance to extinction is a function of N-R transitions, therefore the minimum requirement would be a single block of trials of the order N-R. Alternatively the frustration hypothesis (Amsel, 1958) indicates that an initial reinforcer is required to create an expectation of reward on the proceeding trial. Nonreward following this expectation is proposed to result in frustration which is conditioned to the motor response by a future reinforcer. Based on this analysis, the minimum requirement for evidence of a PRE would be predicted to be three trials with an R-N-R sequence. No PRE would be predicted to be established following exposure to the partial (N-R) reinforcement condition of the present experiment.

The results of this study do not support the establishment of a PRE following a single N-R transition as predicted by the sequential aftereffects hypothesis. Neither the male nor the female partial (N-R) reinforcement groups showed any indication of a PRE, but rather the continuous (R-R) group consistently emitted more responses during extinction. While these results

do not provide direct support for the sequential aftereffects hypothesis, they are not necessarily inconsistent with predictions offered by the frustration model.

Considering the frustration hypothesis within the broader framework of the Hullian theory of learning, these results become more coherent. In 1952, Hull (Hilgard & Bower, 1975) postulated that the probability of a response ($_sE_r$) is a geometric function of habit strength ($_sH_r$), drive (D), stimulus intensity (V), and incentive motivation (K). In the present study, stimulus intensity and incentive motivation have been held constant. Furthermore, drive reduction may be assumed to be minimal with only two reinforcers. Therefore, the model reduces to response strength being a direct function of habit strength, which is the only remaining factor. In this model, habit strength is a function of the number of successive reinforcements. Based on this foundation, the order of conditions in relation to frequency of responding should be R-R, N-R, and N-N. Furthermore, given the summational nature of rewards in increasing habit strength, the three conditions should be at equally spaced intervals. These predictions were supported by the present study, both in the order and interval between conditions. While these results are not directly supportive of the frustration model, they are consistent with the model and the Hullian framework from which it was derived.

Previous research has obtained conflicting results concerning the PRE following limited acquisition trials, with some evidence of a PRE for an N-R condition. As proposed in the introduction,

this PRE may be the result of habituation and/or the use of multiple (or large) reinforcers. With repeated habituation trials and interspersed feeding, the potential for the conditioning of anticipatory avoidance to the motor response remains. Additionally, multiple (or large) reinforcers provide the opportunity for multiple approach and avoidance responses within a single trial. The potential impact of these confounding variables was avoided through the elimination of a habituation period and the use of a single high preferability reinforcer.

The female group exhibited a significantly higher response rate relative to the male group for all conditions. Rather than necessarily being a sex-related difference, alternative variables were inadvertently associated with sex. The female group had previously received handling and bar press training in a Skinner box for food reinforcement. Observations of these subjects throughout the measurement period indicated that they frequently twisted their heads in the feeder trough and spent a large amount of time with their heads in the trough. These behaviors are similar to those the rats directed at the pellet dispenser in the Skinner boxes and may have contributed to their tendency to emit more responses than their male counterparts. Furthermore, prior handling may have led to a reduction in anxiety associated with novel conditions, thus increasing activity levels. Despite sex differences in the rate of exploration, the order of reinforcement conditions in reference to responses remained consistent across both groups.

In conclusion, the results of the present study clearly provide no support for the sequential aftereffects hypothesis (Capaldi, 1970) since no indication of a PRE was obtained following a single N-R transition. Alternatively, these results are consistent with predictions of the frustration hypothesis (Amsel, 1958). This model implies that an initial reinforced trial must precede an N-R transition in order to create an expectation of reward. Future experimentation may focus on the prediction as offered by the frustration hypothesis with the inclusion of an R-N-R condition. Should a PRE be established following three trials (R-N-R), the critical feature underlying resistance to extinction may be identified as reinforcement following frustrating conditions (unmet expectancy). The results of this study are also supportive of the Hullian contention that habit strength is a function of the summation of successive rewards. Finally, the exploratory response, with its potential for minimizing the variables of handling and habituation, may prove useful in investigations concerning this area.

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