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Mark Randall Cole

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AN INVESTIGATION OF THE PARTIAL REINFORCEMENT ACQUISITION EFFECT USING A DISCRETE-TRIAL LEVER-PRESSING RESPONSE

by

Mark Randall Cole
Department of Psychology

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Faculty of Graduate Studies
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ABSTRACT

Whereas partial reinforcement often leads to better performance than continuous reinforcement in the runway, this has usually not been the case in a discrete-trial lever-pressing situation. Furthermore, there have been only a few adequate demonstrations of a similar effect in the free-operant situation.

In the first of five experiments designed to provide clarification of this discrepency, rats received either 100% or 50% reinforcement in a discrete-trial lever-pressing situation where a response was defined as 10 lever presses. Ss received 360 trials with each response leading to a 15-second intertrial interval and also producing reinforcement on reinforced trials. Throughout acquisition, 50% reinforcement led to longer latencies and longer response times than 100% reinforcement.

In Phase I of a second study, 600 discrete trials under conditions of 100% reinforcement of FR10 responses were given in an attempt to eliminate competing responses. Following this, in Phase II, one group (G100) received a further 600 discrete trials on 100% reinforcement while three other groups (G70, G50 and G30) were switched to 70%, 50% and 30% reinforcement, respectively, and a further 600 trials were administered. Analysis revealed that G50 had longer latencies than G100 or G70 and that G30 demonstrated longer response times than G70 or G50, but no other group differences were significant. Further analysis revealed that while 50% reinforcement led to significantly slower response times than 100% reinforcement during Days

1-15 of Phase II, there was a crossover beginning on Day 18. That is, G50 responded faster than G100 from Day 18 until Day 30, but this difference was not statistically significant. These data suggest that while partial reinforcement produces different effects on the performance of the running and lever-pressing responses by rats, it is possible that these differences are of a quantitative rather than a qualitative nature, perhaps occasioned by differences in response preparedness.

In Experiment III, an hypothesis that the failure to obtain a significant PRAE in Experiment II was due to a ceiling effect was tested by using another paradigm which has been shown to facilitate performance - behavioral contrast. A MULT (FR10-VI30 second) schedule was switched to a MULT (FR10-EXT) schedule for each of 6 rats. Results showed that following this change, mean FR pause time increased and mean FR local response rate declined, relative to baseline performance. This failure to observe behavioral contrast was discussed in terms of the punishing effect of response-produced time out.

In a fourth study, strain (Wistar or Long-Evans rats), intertrial interval duration (15 or 0 seconds) and percent reinforcement (100% or 50%) were varied in an attempt to further clarify the role of the intertrial interval (time out) in a discrete trial lever-pressing situation. The tenth lever press on each trial sounded a 5-second buzzer, caused the lever to retract for 15 or 0 seconds and produced reinforcement on reinforced trials. Training was continued

for 400 trials. Analysis revealed that response times during lever presses 1-6, 6-10 and 1-10 of the FR10 response unit were longer when the intertrial interval was 0 seconds than 15 seconds, providing no support for the hypothesis that the intertrial interval was a time out which punished partially reinforced responding more than continuously reinforced responding. The lack of a difference between 100% and 50% reinforced responding, on the other hand, suggests the importance of exteroceptive stimuli, such as the buzzer in the present experiment, in this type of situation.

Finally, in a fifth study, the hypothesis that a longer intertrial interval (time out) would punish FR10 responding, was tested. Three levels of intertrial interval duration (60, 15 or 0 seconds) were compared for 100% reinforcement of discrete-trial FR10 responses. Training was continued for 360 trials. Analysis revealed no differences as a function of intertrial interval duration for response times during lever-presses 1-6, 6-10 or 1-10 of the FR10 response unit, thus providing no support for the hypothesis that in a discrete-trial lever-pressing situation, the intertrial interval is a time-out punisher.

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GENERAL INTRODUCTION

The Partial Reinforcement Acquisition Effect in the Runway

A reinforcer may be defined as any stimulus, contingent on a response, which increases the future probability of that response. Reinforcers (e.g., food for a hungry organism or water for a thirsty organism) may be presented following every response (continuous reinforcement) or following some percentage of the total number of responses (partial reinforcement). On the other hand, reinforcers may not be presented at all for responding (extinction), a condition which eventually results in the cessation of responding. The degree to which an organism persists in responding during extinction is called resistance to extinction.

Research on the effects of partial reinforcement of responding has been mainly concerned with the effects of partial and continuous reinforcement during acquisition of a response on subsequent extinction performance. Almost without exception, it has been shown that partial reinforcement of responding leads to greater resistance to extinction than continuous reinforcement in a wide variety of species and response situations. Attempts to explain this phenomenon have led to the emergence of numerous theories by such contemporary theorists as Amsel (1958, 1962) and Capaldi (1967).

An area which has been largely neglected, however, is that dealing with the effects of partial reinforcement on the acquisition of responding. In their massive review of the literature dealing with partial reinforcement, Jenkins and Stanley (1950) concluded that performance under a partial schedule of reinforcement tends to be lower than that under a continuous one. A similar review of the partial reinforcement literature by Lewis (1960) failed to even discuss acquisition data. A more recent review, however, (Robbins, 1971) documents a number of studies comparing acquisition performance under conditions of continuous and partial reinforcement.

An apparatus called the straight runway has often been used to compare the effects of random partial reinforcement and continuous reinforcement on the acquisition of a running response. In such experiments, S is placed in a small chamber called a start box and when a door separating the start box from a longer chamber called the runway is opened, S is permitted to run down the runway to a chamber called a goal box which is located at the opposite end. A food cup or some other type of reinforcer dispenser is located in the goal box and a run from start box to goal box is called a trial. Continuously reinforced Ss find a reinforcer in the food cup on every trial while partially reinforced Ss find a reinforcer on only a random percentage of the trials. Following consumption of the reinforcer (or following a period of goal box confinement on nonreinforced trials), S is removed from the apparatus and placed in his home cage to await the next trial. The intertrial interval may be as short as a few seconds or as long as 24 hours. Latency (the time it takes S to leave the start box) and running time (the time elapsed before S reaches the goal box) are usually measured as dependent variables. Sometimes, however, running time is recorded separately in successive segments of the runway.

One of the first demonstrations of what is now termed the Partial Reinforcement Acquisition Effect (PRAE) was carried out by Goodrich (1959). Rats were reinforced for running in a runway on either 100% or 50% of the trials. When start speed was measured in the first 6 inches of the runway, 50% reinforcement appeared to lead to slower running speed during Trials 1-12, but following this there was a crossover, and at asymptote 50% reinforcement led to superior performance. Analysis of variance revealed that while the partial group did not run significantly slower on Trials 1-12, they ran significantly faster than the continuous group after Trial 12. When running speed was measured in the second 6 inch portion of the runway, the same crossover effect appeared after Trial 20 but the groups were not significantly different before or after the crossover. When goal-box speed was measured in the last 12 inches of the runway, partially reinforced rats ran significantly slower than those on continuous reinforcement and there was no indication of a crossover. A replication of the experiment produced essentially the same results except that partially reinforced rats ran significantly faster in the run segment at asymptote as well as in the start segment. In addition, there were no differences in goal-box speed between the groups at asymptote.

Another study of acquisition under conditions of partial and continuous reinforcement was carried out by Weinstock (1958). Using several percentages of randomized reinforcement in the runway, he found that even when training was carried out at the rate of one trial per day, partially reinforced rats ran slower than continuously reinforced rats early in acquisition but demonstrated faster speeds late in training.

Wagner (1962) varied percentage of reinforcement as well as magnitude of reinforcement in the runway. The results showed that the continuously reinforced group ran faster until Trial 16 at which time the group receiving 50% reinforcement crossed over and at asymptote was running faster than the continuous group. However, these results were obtained only when reciprocal latency of leaving the start box and running speed in the runway were measured. When running speed in the goal region was measured, continuous reinforcement led to faster speeds than partial reinforcement throughout training. Finally, the magnitude of the PRAE was found to be greater with 1.0 than with .08 gm reinforcers.

Spence (1960) made use of Amsel's frustrative nonreward theory to explain these data. The theory assumes that reinforcement leads to a large unconditioned goal response (R_G). An example of such an R_G response might be salivation. A classically conditioned fractional anticipatory goal response (r_G) soon comes to be elicited by the interoceptive and exteroceptive stimuli in the goal box region. With repeated training, these r_G responses, together with their stimulus components (s_G), come to be elicited further and further back in the runway through stimulus generalization. It is assumed that this r_G-s_G mechanism becomes attached to and serves to elicit the running response in the runway. Introduction of nonreinforcement into the situation is assumed to result in a large unconditioned frustration response (R_F) in the goal box on nonreinforced trials, provided the r_G-s_G mechanism has already developed. As is the case with R_G, a classically conditioned fractional anticipatory frustration response (r_F) is assumed to become elicited by the stimuli in the goal box area and through generalization, this response comes to be elicited further back in the runway. The r_F-s_F mechanism is assumed to have two functions. First, it tends to elicit responses which compete with running although the exact nature of such responses is not specified. Secondly, r_F-s_F is assumed to add to the generalized drive level of the organism. The presence of the two anticipatory mechanisms in the situation initially leads to a conflict situation according to Amsel's theory. This conflict is resolved, however, since only by running can the organism obtain whatever reinforcement is scheduled. Since running occurs, r_F-s_F becomes conditioned to the running response and competing responses disappear. The drive incrementing function of r_F-s_F remains, however, and leads to faster running speed than that occurring under conditions of continuous reinforcement. This theory explains the initial inferiority of partially reinforced responding since, early in training, competing responses are present and r_G is not sufficiently developed to lead to a strong R_F response on nonreinforced trials. According to Amsel (1958), it also accounts for the inferiority of partially reinforced organisms in the goal region. As a function of the generalization gradient, a very strong r_F response is evoked in this area and not all of the competing responses elicited by this mechanism disappear. These persistant competing responses interfere with the running response and slow down the partially reinforced organism. Support for this theory has been provided in a wide variety of experimental demonstrations of the motivating effect of nonreinforcement (Amsel, 1958, 1962; Amsel and Roussel, 1952; Gallup and Hare, 1969; Cole and Van Fleet, 1970).

Several investigators have measured competing responses and running concurrently and provided further support for this theory.

McCoy and Marx (1965) replicated the findings of Weinstock (1958), Goodrich (1959) and Wagner (1962), demonstrating a PRAE in the runway. In addition, however, these investigators also measured halts in excess of 0.5 seconds and reversals in direction as the rats traversed the runway. These data revealed that more of these competing responses were associated with 50% reinforcement early in training but that at asymptote, 50% reinforcement led to fewer competing responses than 100% reinforcement. In addition, 50% reinforcement led to a greater number of competing responses in the goal-box region than 100% reinforcement throughout training. These data are consistent with Spence's frustration-competing response interpretation of the PRAE.

Harris, Smith and Weinstock (1962) also attempted to measure competing responses during the establishment of a PRAE. While 50%

reinforcement led to significantly faster running speeds than 100% reinforcement, no differences were observed in the variability of the path taken by rats as they ran down the runway. This measure involved lateral deviations from a straight path, however, and the stops and reversals measured by McCoy and Marx may have been better measures of the competing responses referred to by Spence.

It should also be emphasized that the PRAE has not always been demonstrated in the runway (Logan, 1960; Longstreth, 1964). Lobb (1968) has provided an explanation within the framework of Spence's theory which accounts for these failures. He points out that in these latter studies, the duration of nonreinforced goal confinement (DNC) was close to zero. Lobb points out that when DNC $>$ 0, the cues associated with nonreinforcement become salient and elicit R_F. Subsequent removal from the goal box, however, is reinforcing and reduces R_F. As a result, removal from the goal box before the cues associated with nonreinforcement have become salient leads to a large R_F response which is not reduced. This in turn is assumed to lead to a very strong r_F response in the start box and runway, not just in the goal region. Lobb goes on to say that, as a result, competing responses are not completely eliminated and the inferiority of partially reinforced responding, usually found only in the goal area, occurs in the start and run measures as well. By making the cues associated with nonreinforcement immediately salient, Lobb (1968) was able to demonstrate a PRAE even when the DNC was zero seconds.

At least one study, however, (Roberts, 1969) failed to demonstrate a PRAE even though the DNC was 20 seconds. Ten groups of rats, five run under continuous reinforcement and five run under 50% reinforcement, were trained in a straight runway at the rate of one trial per day. The five groups within each reinforcement schedule received either 1, 2, 5, 10 or 25 pellets (.045 gm) on reinforced trials. Results showed that start, run and goal speeds were an increasing function of reinforcement magnitude. In addition, there was no difference between 100% and 50% reinforcement groups for start or running speed, but when goal box speed was measured 50% reinforcement led to slower asymptotic responding than 100% reinforcement.

Summary. The results of studies, carried out in the runway, which were designed to compare continuous with partial reinforcement of running, would seem to support the following general conclusion: (1) in portions of the runway remote from the goal box, partial reinforcement leads to inferior performance, relative to continuous reinforcement, in early acquisition (Trials 1-20); (2) in portions of the runway remote from the goal box, partial reinforcement leads to superior performance, relative to continuous reinforcement, at asymptote; (3) in portions of the runway close to the goal box, partial reinforcement leads to inferior performance, relative to continuous reinforcement, throughout acquisition (100-200 trials); and (4) some studies have shown partial reinforcement to lead to inferior performance, relative to continuous reinforcement, in all portions of the runway, throughout acquisition.

Free-Operant Responding in the Skinner Box

Another apparatus which has often been used to compare the effects of partial and continuous reinforcement is called the Skinner box. The typical Skinner box is a small chamber containing some kind of manipulandum (i.e., a lever, pedal or key), some device to deliver reinforcers (i.e., a pellet dispenser or liquid feeder) and some type of exteroceptive stimulus (i.e., a buzzer or cue light). In the free-operant responding situation, organisms are free to respond on the manipulandum (i.e., press the lever or peck the key) as long as they remain in the Skinner box. Unlike the runway situation, the free-operant situation involves no discrete trials. In addition, reinforcers may be presented, contingent on responding, in a variety of ways.

In interval schedules, reinforcers become available only after the passage of a period of time.

In a fixed-interval (FI) schedule, the first response following a fixed interval of time, measured from the last reinforcer, is reinforced. For example, in an FI10-second schedule, the first response following the passage of 10 seconds is reinforced. When the interval is measured in minutes, however, it is customary to omit the word "minute" when describing the schedule. Thus a fixed-interval one minute schedule is usually designated as simply, FI1.

A variable-interval (VI) schedule is similar to an FI schedule except that the intervals of time vary from reinforcer to reinforcer and only the mean interval is specified. For example, in a VI1 schedule, reinforcers are scheduled for delivery, contingent on a response, after a period of time which may vary between 0 seconds and 2 minutes with a mean value of 1 minute.

Responding may also produce reinforcers on a ratio schedule in the free-operant situation.

A fixed-ratio (FR) schedule is one in which the first response following a fixed number of responses is reinforced. The simplest FR schedule is FR1, usually called continuous reinforcement (CRF). In this schedule, every response is reinforced. In an FR10 schedule, on the other hand, every tenth response is reinforced.

A variable-ratio (VR) schedule is similar to a fixed-ratio schedule except that the ratio varies from reinforcer to reinforcer and only the mean ratio is specified. For example, in a VR10 schedule, the response:reinforcer ratio may vary from 1:1 to 20:1 with a mean value of 10:1.

Compound schedules may also be constructed using these simple schedules as components.

A multiple schedule is one in which two (or more) components, each producing reinforcement on some schedule and each identified by a different discriminative stimulus, alternate in a predetermined fashion. For example, in a multiple FR10-VI3 [MULT(FR10-VI3)] schedule, responding produces reinforcement on an FR10 schedule in the presence of one stimulus (e.g., a red light) while reinforcement occurs on a VI3 schedule in the presence of another stimulus (e.g., a green light).

A mixed schedule is similar to a multiple schedule except that there are no separate discriminative stimuli associated with the various components. For example, in a mixed FR10-VI3 [MIX(FR10-VI3)] schedule, either the FR10 component or the VI3 component may be in effect at any given time. Thus the pattern of reinforcer delivery is the only cue as to which component is in effect.

A chain schedule is also similar to a multiple schedule except that primary reinforcement (e.g., food) occurs in the terminal component only. For example, in a chain FR10-VI3 [CHAIN (FR10-VI3)] schedule, ten responses in the presence of one stimulus (e.g., a red light) produce the stimulus associated with the other component (e.g., the green light) but no primary reinforcement. Responding in the presence of the green light, on the other hand, produces primary reinforcement on a VI3 schedule.

A tandem schedule is similar to a chain schedule except that separate discriminative stimuli are not associated with the different components. For example, in a tandem FR10-VI3 [TAND(FR10-VI3)] schedule, ten responses switch the schedule to VI3 in which responding produces primary reinforcement.

Investigations of partial reinforcement effects in free-operant situations, like those in discrete trial situations, have also concentrated on performance during extinction; and, as in the runway, the results of those studies reporting acquisition data have been quite equivocal.

Skinner (1938) using a free-operant lever-pressing response with rats, presented either FR48, FR96 or FR192 in a mixed schedule MIX(FR48-FR96-FR192) . Both reciprocal pause time and local response rate (not including pause time) were found to be increasing functions of ratio size.

In another operant study, Jenkins, McFann and Clayton (1951) found that rate of responding on VI1 was five times that on CRF. One problem in comparing CRF to any schedule of partial reinforcement is that more reinforcers are obtained per unit time on CRF and hence more time per session is spent consuming pellets, not responding. This problem is controlled for in discrete-trial experiments by scheduling reinforcers during an intertrial interval, the duration of which exceeds consumption time. In the foregoing study, pigeons on CRF spent 50% of the session consuming pellets while those on VI1 were engaged in consummatory responses only 10% of the time. When the groups were matched on this score, however, VI1 still generated a rate twice as high as that produced by CRF.

Likely (1958) in a similar comparison between groups of rats, found that a VI3 schedule of reinforcement led to lower rates of responding than CRF. Only 107 reinforcers were obtained on the partial schedule over a four hour period, however, as compared with 400 reinforcers obtained on CRF in much less time. As a result, the rate of reinforcement for the partial group was very low (0.5 per minute) and this coupled with the limited training may explain the discrepancy between the results of this experiment and those of Jenkins et al. In any case, since CRF or FR1 is a ratio schedule, it might have been more meaningful to compare it with FR or VR schedules of partial reinforcement.

Using a licking response in rats, Hulse and Bacon (1962) compared CRF to FR8 in a free-responding situation where the reinforcer was 0.25, 0.50, 1.80, 4.50 or 10.00 gm of saccharine in one liter of water. At all levels of concentration, CRF was found to lead to higher response rates than FR8. This finding does not agree with results often obtained using the lever-pressing or key-pecking responses. One possible explanation is that rats on CRF were always licking a wet tube which provided lubrication. Many of the licks on the FR8 schedule were on a dry tube, however, which may account for the low rates.

In a within-Ss study with rats, Pavlick, Carlton and Manto (1965) correlated CRF with responding on one lever and VR3 with responding on a second lever in a two-lever Skinner box. When the cue light over one of the levers was lighted, responding on that lever was reinforced according to the appropriate schedule and responding on the unlighted lever produced no reinforcement. In the first experiment the position of the lighted lever changed after 10 responses had been made on the lighted lever, thus equating responses (60) to the two levers. In the second study, the position of the lighted lever changed after 10 reinforcers had been obtained as a result of responding on the lighted lever, thus equating reinforcers (40) on the two levers. In both experiments, overall response rate was higher on the lever associated with VR3, but latencies (time from the onset of the cue light until the first response) were longer on this lever. This latter finding may be due to the fact that very little training was given and responding, in all probability, was not asymptotic.

In a similar study, Dutch (1968) placed rats on a MULT (FR2-CRF) schedule of reinforcement where the components changed in a random fashion. In a second experiment, rats were placed on a MIX (FR5-CRF) schedule where the components alternated every two minutes. Half the rats always had CRF with the house light off in the first experiment. This was reversed for the other half of the Ss. In the first study, rats made 800 responses, 400 under each schedule, while in the second experiment, rats received 80 minutes of training, 40 in each component. Ss in the second study made 384 responses on CRF and 468 responses on FR5. As a result, response rates were more likely to be asymptotic than in the previous experiment by Pavlick, Carlton and Manto (1965). The results of the first experiment showed that while FR2 yielded lower response rates than CRF during the first 6 days of training, this relationship reversed on Days 7 and 8 with FR2 generating higher terminal rates. In the second experiment, responding on FR5 led to higher rates than CRF on Days 2-10. While between-Ss comparisons are not necessarily meaningful in this case due to differences between the experiments, it is interesting to note that response rates on CRF were approximately equal in the two studies (9.6 and

9.9 responses per minute). The FR5 schedule in the second experiment, however, generated higher rates than FR2 in the first study (11.9 and 9.9 responses per minute).

In a study designed to compare partial reinforcement with continuous reinforcement both between- and within-Ss, Pavlick and Carlton (1965) exposed one group of rats to a CRF schedule, 10 minutes per day for four days. Another group was exposed to a VR3 schedule for the same periods. For both of these groups, the left and right cue lights were alternately illuminated every 30 seconds. A third group was placed on a MULT (VR3-CRF) schedule of reinforcement with one or the other of the cue lights correlated with each component in a counterbalanced fashion. As for Groups 1 and 2, the cue lights and hence the schedule, changed every 30 seconds. Ten minutes of training on each schedule were given for 4 days. Results in both the between- and within-Ss comparisons showed that terminal acquisition rates were higher for VR3 than CRF. In addition, while CRF rates were about equal in Groups 1 and 3, VR rates were higher in Group 2 than in the VR component of Group 3.

In a replication of the previous study, Pavlick, Lehr and Hendrickson (1967) used an identical procedure except that 22 rather than 4 days of training at the rate of 10 minutes per day were given. Results after 4 days of training agreed with those found by Pavlick and Carlton (1965) with VR rates higher than CRF rates in both the between- and within-Ss comparisons. Also, the

VR component of MULT (VR3-CRF) led to lower rates than the VR schedule. By Day 22, however, this difference between the VR rates had disappeared due to an increase in response rate in the VR component of the MULT (VR3-CRF) schedule.

In another within-Ss design, Neuringer and Chung (1967) trained pigeons on a TAND (FR1-FI5-second) schedule. A key peck (FR1) initiated a 5-second interval (FI5-second) and the first response following the interval was reinforced with a 3-second access to food. In the 100% reinforcement condition, responding in each FI5-second component produced a reinforcer. When stable responding was achieved, however, the schedule was changed so that responding in only 15% of the FI5-second components resulted in reinforcement. The other 85% of the FI5-second components terminated in a blackout of varying duration (7.0, 1.0, 0.25 or 0 seconds), during which the entire box was darkened. Results showed that FI5-second response rates (not including responding during the reinforcement or blackout events) were lower when only 15% of the FI5-second components were reinforced than when 100% of these components were reinforced. This was particularily true when the nonreinforced trials did not terminate in a blackout. This experiment like that of Skinner (1938), controlled for the effects of consummatory time, since local FI response rates, not overall FI response rates, were measured.

In another free-operant study which controlled for the effects of consummatory time, Zeiler (1972) placed pigeons on three different fixed interval schedules (FI8, FI4 or FI2). Following the establishment of stable responding, the situation was changed so that various percentages (90%, 70%, 50%, 30% or 10%) of the FIs terminated in a 4-second key-colour change but no reinforcement. A return to the baseline condition, in which 100% of the FIs were reinforced, preceded each change to a new partial reinforcement schedule. Results showed that FI response rate (not including responding during the 4-second reinforcement or nonreinforcement event) was an inverted U-shaped function of percentage reinforcement. Decreasing the percentage of reinforced FIs to 90%, 70% or 50% resulted in progressively increasing rates of responding while further decreases in percentage reinforcement led to decreases in response rate.

Summary. The results of these studies would seem to support the conclusion that in free-operant responding, partial reinforcement produces performance superior to that generated by continuous reinforcement provided the percentage of reinforced responses is not too low. This is especially true when terminal rather than early acquisition performances are compared. These conclusions are not inconsistent with the results often found in runway studies.

Discrete-Trial Responding in the Skinner Box

In recent years, a number of investigators have used a discrete-trial Skinner box analogue of the runway in an attempt to compare the free-operant lever-pressing and key-pecking responses with the running response used in the runway. The intention has been to make the Skinner box and runway situations as similar as possible in studying the behavioral laws which govern each situation. In the typical experiment making use of a discrete-trial Skinner box analogue of the runway to compare continuous with partial reinforcement, a discrete trial procedure is introduced as soon as possible. This is accomplished by making the manipulandum (e.g., the lever) available only during a specified time called a trial. A reinforcer is presented, contingent on responding, at the end of every trial for continuously reinforced Ss, but only at the end of a random percentage of the trials for partially reinforced Ss. At the end of each trial the manipulandum is removed for a period of time termed the intertrial interval. In experiments using pigeons, the entire box is darkened during the intertrial interval, a condition in which key-pecking seldom occurs. As in the runway situation, this intertrial interval can vary over a wide range but is usually less than 1 minute in the discrete-trial Skinner box situation. Thus, the discrete trial Skinner box situation is similar to the runway in that discrete trials are employed but is like the free-operant situation with respect to response topography.

Roberts, Bullock and Bitterman (1963) compared partial and continuous reinforcement of a pecking response in pigeons using a discrete-trial procedure. Pigeons were trained in daily sessions of 20 trials for 26 days with an intertrial interval (ITI) of 6 seconds during which the key was dark and reinforcement was not available. Three groups of birds were reinforced on a CRF schedule for the first 7 days but beginning on Day 8, one group was switched to a random 50% reinforcement schedule and a second group to an alternating 50% schedule. In an alternating 50% reinforcement schedule every other response is reinforced. The third group remained on CRF throughout acquisition. Analysis of the results showed that while the partial groups did not differ, both showed longer mean log latencies at asymptote than the group receiving continuous reinforcement.

Zimmerman (1960) used a multiple schedule to compare continuous with partial reinforcement where the response requirement was either 1 or 10 lever presses. During the first stage, rats were reinforced on either a MULT (CRF-EXT) schedule or MULT (FR10-EXT) schedule. The extinction (EXT) component, during which responding was not reinforced, was 2 minutes in duration. For Ss on the MULT (CRF-EXT) schedule, a single lever press was followed by reinforcement and EXT and for Ss on MULT (FR10-EXT), ten lever presses led to reinforcement and EXT. These components were alternated regularly and since response rate fell to zero during the 2-minute EXT component, this period was analogous to an ITI during which responding did not occur. Following this, a random half of the reinforcers for responding on CRF or FR10 were omitted. The effect of this intermittency was to produce an overall increase in latency and an increase in variability of latencies for both the CRF and FR10 responses. Unfortunately, no data are available to show the effect of partial reinforcement on local response rate (excluding latency) for the FR10 group.

In another factorial design, Marx (1967) varied percentage of reinforcement (100%, 75%, 50% or 25%) and magnitude of reinforcement (1, 4 or 16 20mg food pellets) using twelve groups of rats. A response was defined as a single lever press which produced a reinforcer on reinforced trials and was followed by a 55-second ITI during which the lever was retracted. Onset of a trial began with the introduction of the lever. Eight trials of training per day were given for 22 days and response latencies were recorded on each trial. An analysis of variance yielded a significant Percentage Reinforcement factor but insignificant Magnitude and interaction factors. While comparisons between the 100, 75, 50 and 25 percent groups were not provided, it appears from the data that mean latency was a decreasing function of percentage reinforcement. The Percent Reinforcement factor was still significant when only data from the last 18 days of training, where responding appeared asymptotic, were analyzed.

In a similar experiment, Uhl and Young (1967) varied percent reinforcement (75%, 50% or 25%), sucrose concentration (13.5%, 27% or 48%) and number of nonreinforced responses (90, 180 or 360) in a 3 x 3 x 3 factorial design. In a separate factorial design, the three sucrose concentrations were varied with total number of trials (180, 360 or 720) for nine groups of rats on CRF. A response was defined as a single lever press and each response was followed by withdrawal of the lever and a 7-second ITI. Training was carried out at the rate of 60 trials per day until the proper number of trials had been completed for each group. Cumulative latencies were recorded for each block of 10 responses. Analysis of variance revealed significant Percentage Reinforcement, Sucrose Concentration and Nonreinforced Trials factors. Latencies were a decreasing function of concentration while 180 nonreinforced trials led to the shortest latencies when compared with 90 or 360 nonreinforced trials. While comparisons between the percentage reinforcement groups were not provided, latency appears to have been a decreasing function of percentage reinforcement.

Porter and Kopp (1967) also used rats in a discrete-trial lever-pressing situation to examine the effect of percentage reinforcement of an FR12 response. Group 100 received sucrose reinforcement on every trial while Group 50C was reinforced on a random half of the daily trials. On nonreinforced trials, a dipper click was sounded after the twelfth lever press for this group. Group 50C-NC was also placed on a 50% reinforcement schedule but no dipper click was presented on nonreinforced trials. The ITI was 30 seconds for all groups and training was continued for 2 days at the rate of 40 trials per day. Start speed, which was the reciprocal of the time from the start of lever insertion until the first lever press, was fastest for Group 100, slower for Group 50C-NC and slowest for Group 50C during the last 20 trials of training. Chain speed, which was the reciprocal of the time from the first lever press until the twelfth, did not differ as a function of percentage reinforcement during the last 20 trials.

In the first of two studies, Marx (1969) varied percentage reinforcement (100%, 75%, 50% or 25%) with training distribution (daily or weekly). Rats in the daily training groups were given eight trials per day for 10 days while those in the weekly condition received eight trials each Friday for 10 weeks. A single response on the lever produced reinforcement on trials for which a reinforcer was scheduled and caused the lever to withdraw for 30 seconds (ITI). Analysis of variance of mean latencies over total training yielded significant effects of both percentage reinforcement and distribution. Further analysis showed that weekly training led to longer latencies than daily training but as in previous studies no comparisons between percentage reinforcement levels were provided. Inspection of the data, however, showed that for daily training, latencies appeared to be a decreasing function of percentage reinforcement. In weekly training, on the other hand, no clear difference emerged between Groups 100, 75 or 50 but all three appeared to have shorter latencies than Group 25.

McMillan (1971) used pigeons in a within-Ss design to examine the effect of partial reinforcement of FR30 responses. During baseline training, each FR30 terminated in a 3.5-second access to food followed by a 0.5-second blackout during which the entire box was darkened. Following the attainment of stable performance, the situation was changed so that a random 20%, 40% or 70% of the ratios terminated in a 4-second blackout but no reinforcement. A return to baseline conditions was always effected before switching to a new partial reinforcement schedule and the order of partial schedules was counterbalanced across birds. Results showed an increase, relative to baseline performance, in post-reinforcement pauses when 40%, 50% or 70% of the ratios terminated in nonreinforcement. No change in post-reinforcement pauses was observed when 20% of the ratios were nonreinforced. On the other hand, a decline in pause time following nonreinforcement, relative to baseline performance was observed in all partial schedules. These data revealed an overall decline in pause time (collapsed over reinforcement and nonreinforcement) following a shift from 100% reinforcement of FR30 runs to a partial reinforcement schedule. It is interesting to note that when the blackout following reinforcement was increased to 12.5 seconds (16 seconds on nonreinforced trials), thus more closely approximating the typical discrete-trial situation, there was an overall increase in pause times, relative to baseline performance, following a shift to partial reinforcement of FR30 runs. Thus, these latter data reveal inferior performance under conditions of partial reinforcement of FR30 responses when such ratios are separated by an intertrial interval of substantial length. It is unfortunate that performance during the FR chain itself was not measured as well.

In another factorial experiment, Tombaugh, McCloskey and Tombaugh (1971) used a discrete-trial lever-pressing situation to compare the effects of sucrose concentration (64% or 8%), delay of reinforcement (12 or 0 seconds) and percentage reinforcement (100% or 50%). Training was carried out at the rate of 10 trials per day for 28 days during which a single lever press resulted in retraction of the lever for 60 seconds and delivered a reinforcer on reinforced trials. Results showed that 64% sucrose led to shorter latencies than 8% sucrose whereas immediate reinforcement produced shorter latencies than delayed reinforcement. In addition, 100% reinforcement resulted in shorter latencies than 50% reinforcement.

Zeiler (1972) carried out a discrete-trial investigation of partial reinforcement similar to the free-operant study described previously. The same three pigeons were placed on three separate FI schedules (FI8, FI4 or FI2, respectively). In this study, however, each 4-second reinforcer presentation was followed by a 10-second blackout during which the chamber was darkened and no responding occurred. When stable performance had been obtained, the situation was altered so that various percentages of the FIs terminated in a 4-second key-colour change followed by a 10-second blackout but no reinforcer. The percentages of reinforcement employed were 90%, 70%, 50%, 30%, 10%, 7% and 0% and a return to a 100% reinforcement condition always preceded a change to a new partial reinforcement condition. Results were quite different from those observed in the free-operant experiment. FI response rate (not including responding during the key-colour change, reinforcement or the blackout) declined as the percentage of reinforced trials was reduced although the reduction was slight until the reinforcement percentage was reduced below 50%.

In a second study, Marx (1969) varied percentage of reinforced trials in magazine training (100% or 50%) with percentage of reinforced trials in lever-press training (100%, 50% or 25%). The procedure was essentially the same as in the previous study except that training was carried out at the rate of eight trials per day for 18 days and the ITI was 55 seconds. Analysis of variance of latencies revealed a significant Lever-Press Percentage Reinforcement factor and a significant Lever-Press Percentage Reinforcement x Trials interaction. The Magazine Percentage Reinforcement factor, however, was not significant. From the data it appears that over the first 10 days of training, mean lever-press latency was longer for Group 25 than for Groups 50 and 100 which did not differ. At asymptote, however, there appeared to be no difference among any of the groups.

In another discrete-trial study, Gonzales and Bitterman (1964) varied percentage reinforcement (30% or 60%) and number of nonreinforced trials in succession (small or large) in a factorial design. A fifth group of rats received 100% reinforcement for responding on the lever. A response was defined as a single lever press and each response produced a reinforcer on reinforced trials and on all trials caused the lever to retract for 15 seconds. Ss were given 30 trials per day for 15 days. Analysis of variance of latencies yielded no significant effects and performance at asymptote was equal for all 5 groups.

Gonzales, Bainbridge and Bitterman (1966) compared groups of rats receiving 60% reinforcement, 60% reinforcement with long runs of nonreinforced trials, or 100% reinforcement. For half the Ss in each group, a response was designated as 5 lever presses and for the other half, 20 lever presses constituted a response. A discrete-trial lever-pressing situation was employed with an ITI of 65 seconds and 30 trials per day were administered for 15 days. At asymptote, for the 5-press groups, 60% reinforcement led to shorter latencies than 100% reinforcement but the groups did not differ when response time (time from the first lever press until the last in each FR) was measured. No differences were observed among any of the groups for which 20 lever presses constituted a response.

In a second study by these investigators, 100% reinforcement was compared with random 50% reinforcement, alternating 50% reinforcement and 50% reinforcement with extended runs of nonreinforced trials in succession. A single lever press was defined as a response and the ITI was 30 seconds. Training was administered for 24 days at the rate of 20 trials per day. There were no differences between the groups at asymptote except that the latencies for the alternating 50% group increased concurrently with the development of patterning.

In a further investigation of partial reinforcement of discrete-trial responding in the Skinner box, Porter and Hug

(1965a) varied percentage of reinforcement (100% or 50%) and number of training trials (12, 32, 64 or 96) for rats. Sixteen lever presses defined a response and the 16th lever press on each trial produced a reinforcer on reinforced trials and always led to a 30-second ITI. Analysis of variance revealed that total response rate was a function of number of training trials but the Percentage Reinforcement factor was not significant. A large Trials x Percentage Reinforcement interaction occurred, however, and further analysis showed that while 100% reinforcement produced faster speeds on Trials 21-32, partial reinforcement resulted in superior response rates on Trials 85-96. These data are in agreement with results often obtained in the runway (Goodrich, 1959; Wagner, 1961; Weinstock, 1958).

In a related study, Porter and Hug (1965b) varied number of acquisition trials (32 or 128), percentage reinforcement (100% or 50%) and length of response chain (1 or 8 lever presses) in a 2 x 2 x 2 factorial design. In this study, also using rats, the ITI was 30 seconds and 32 trials per day were given. Results showed that when collapsed over length of response chain and number of acquisition trials, the 50% group demonstrated faster speeds (reciprocal latency) than the 100% groups. Further analysis revealed that for groups receiving 32 acquisition trials, 100% reinforcement led to faster speeds than 50% reinforcement, regardless of length of response chain. However, for the 128 trial groups, 50% reinforcement led to higher speeds than 100%

reinforcement when the response was a single lever press but there was no effect due to percentage reinforcement when 8 lever presses defined a response.

In a study similar to the one carried out by Porter and Kopp (1967), Tombaugh (1970) also trained rats in a discrete-trial lever-pressing situation. For Group 100, a single lever press produced reinforcement followed by a 30-second ITI. For Groups 50-50 and 50-100, on the other hand, half of the daily trials terminated in nonreinforcement. The empty food magazine cycled on nonreinforced trials for Group 50-100 but not for Group 50-50. There was no statistically significant difference between mean log lever-press latencies for these three groups during the 280 trials of acquisition. A replication of the experiment once again revealed no significant difference between the groups after 140 trials of acquisition. Inspection of the data revealed, however, that Group 50-100 appeared to show consistently longer latencies than Group 100 or Group 50-50 throughout acquisition in both experiments. Since the Group factor approached statistical significance, it is possible that pooling the results of the two studies, thus increasing the N, might have resulted in a statistically reliable difference between Group 50-100 and the other two groups. This conclusion is supported by the findings of Porter and Kopp (1967) who found 50% reinforcement to lead to longer latencies when a dipper click was sounded on nonreinforced trials.

Summary. While the results are somewhat equivocal, it may be concluded that partial reinforcement of discrete-trial responding in the Skinner box usually leads to acquisition performance inferior to that generated by continuous reinforcement. In other words, the discrete-trial Skinner box data are generally inconsistent with results obtained in the runway situation and the free-operant situation when continuous and partial reinforcement are compared during acquisition. There is also some indication in these data that strain of rat may be an important variable. The only discrete-trial lever-pressing study to obtain a PRAE (Porter and Hug, 1965a) used hooded rats of the Long-Evans strain while similar studies finding no difference between partial and continuous reinforcement used hooded rats of the Long-Evans strain (Marx, 1969; Porter and Hug, 1965b), albino rats of the CF-Nelson strain (Gonzales and Bitterman, 1964; Gonzales, Bainbridge and Bitterman, 1966) or albino rats of the Sprague-Dawley strain (Tombaugh, 1970). On the other hand, those discrete-trial lever-pressing studies which showed that partial reinforcement led to inferior performance throughout acquisition used albino rats of the Sprague-Dawley strain (Marx, 1967; Tombaugh, McCloskey and Tombaugh, 1971; Zimmerman, 1960) or albino rats of the Wistar strain (Marx, 1969; Porter and Kopp, 1967; Uhl and Young, 1967).

Behavioral Contrast

Positive behavioral contrast is a phenomenon which may be related to the PRAE. At the observational level, the PRAE is characterized by response facilitation when a lower frequency of reinforcement (i.e., partial reinforcement) is introduced into a discrete-trial responding situation. Likewise, according to Reynolds (1961a), positive behavioral contrast is a facilitation of responding in the presence of one stimulus, concomitant with the reduction of reinforcement frequency in the presence of another stimulus. At the explanatory level, Spence (1960) has attributed the faster running speed associated with partial reinforcement at asymptote to frustration which, according to Amsel (1958, 1962), is an emotional response (R_F) to nonreinforcement. In a similar analysis, Terrace (1966b) has suggested that positive behavioral contrast might be a manifestation of emotional responses produced as a consequence of responding in the presence of nonreinforcement. Terrace has shown that when conditions are arranged so that a pigeon never responds in the presence of nonreinforcement during the formation of a discrimination (errorless discrimination), there is no evidence of emotional behaviors such as wing flapping or vocalizations and no behavioral contrast in the presence of the stimuli associated with reinforcement. This is not the case during the formation of a normal discrimination in which the organism, responding in the presence of the stimulus associated with nonreinforcement, often shows emotional behavior and exhibits positive behavioral contrast. In addition, Terrace (1966a) has shown that with extended training on a MULT (VI1-EXT) schedule, pigeons virtually cease responding in the EXT component, and when this happens, behavioral contrast disappears.

A number of investigators have carried out research in an attempt to discover the necessary and sufficient conditions for the production of behavioral contrast.

In one such study, Reynolds (1961a) placed pigeons on a MULT (VI3-VI3) schedule of reinforcement. When responding had stabilized in both components, the schedule was changed to a MULT (VI3-TO) schedule. During the time out (TO) component, the entire chamber was darkened and key pecking was not reinforced; typically, little or no responding occurs in this situation. Finally, the schedule was changed to a MULT (VI3-EXT) schedule. During the extinction (EXT) component, the box remained illuminated but key pecking was not reinforced. The change from MULT (VI3-VI3) to MULT (VI3-TO) resulted in an immediate cessation of responding in the changed (TO) component and a corresponding increase in response rate in the unchanged (VI3) component. The further change from MULT (VI3-TO) to MULT (VI3-EXT) resulted in a gradually declining rate of responding in the changed (EXT) component and a transient increase in rate of responding during the unchanged (VI3) component, relative to the VI3 response rate during MULT (VI3-TO). This suggests that while responding in the presence of nonreinforcement may not be a necessary condition for behavioral contrast, it may lead to a larger contrast effect than that produced by TO. Further support for this conclusion has been provided by Premack (1969) who also showed a larger contrast effect with extinction than with TO.

In another experiment, Reynolds (1961b) demonstrated that total removal of reinforcement from one of the two components of a multiple schedule was not necessary to produce behavioral contrast. Pigeons were trained to key peck on a MULT (VI-FR) schedule. In the first phase, the VI component was held constant at VI3 while the FR requirement was varied (FR75, FR150 or EXT). In Phase 2, the FR component was held constant at FR150 while the VI schedule was varied (VI1.5, VI3, VI6 or EXT). In both cases, response rate in the variable component was found to be a direct function of the reinforcement frequency in that component. Furthermore, in the constant component, rate of responding was an inverse function of the frequency of reinforcement in the variable component. Finally, the rate of responding in the constant component, relative to the rate of responding in both multiple components, was a positive linear function of the frequency of reinforcement in the constant component, relative to the frequency of reinforcement in both multiple components. From this it was concluded that the occurance of positive behavioral contrast is functionally related to the relative frequency of reinforcement in the measured component of a multiple schedule.

It has been observed, however, (Dunham, 1968; Freeman, 1971; Terrace, 1966b) that changes in frequency of reinforcement are usually confounded with corresponding changes in the rate of responding in the variable component of a multiple schedule. As a result, several investigators have attempted to separate these variables.

In one such attempt, Terrace (1968) trained one group of pigeons to peck a key on a MULT (VI1-VI1) schedule of reinforcement while a second group of birds was placed on a MULT (VI5-VI5) schedule. When responding had stabilized, all birds were switched to a MULT (VI1-VI5) schedule. While pigeons originally trained on MULT (VI1-VI1) showed positive behavioral contrast in the VI1 component of the MULT (VI1-VI5) schedule, negative contrast (a decline in response rate) did not appear in the VI5 component of the MULT (VI1-VI5) schedule for birds originally trained on a MULT (VI5-VI5) schedule. Thus, behavioral contrast occurred only when the rate of responding in the changed component of the multiple schedule decreased. Birds originally trained on MULT (VI5-VI5) demonstrated nc contrast even though the relative frequency of reinforcement in the constant component decreased.

In a second experiment, Terrace trained three pigeons to respond on a MULT (VI1-VI1) schedule of food reinforcement. When responding had stabilized, a 70-msec shock was delivered in one component, contingent on key pecking. Shock voltage was adjusted daily to effect a reduction in response rate, relative to the baseline rate, without reducing the frequency of reinforcement in the changed (shock) component. As response rate declined in the changed component, a corresponding increase in rate of responding was observed in the constant component.

Finally, in a third study, six pigeons were trained to respond on a VI1 schedule of food reinforcement. Following the acquisition of stable response rates, the schedule was changed to MULT (VI1-DRL). On the differential-rate-low (DRL) schedule, birds were required to wait at least _x_ seconds between key pecks in order to obtain reinforcement. In this experiment, _x_ was varied between 6 and 8 seconds in order to lower the response rate associated with DRL, relative to the VI1 response rate recorded during baseline, yet maintain equal frequencies of reinforcement in the two components. Three birds showed a decline in DRL response rate and a concurrent increase in response rate in the constant component (VI1). The remaining birds showed no decline in DRL response rates and no behavioral contrast. These data reveal that a change in relative frequency of reinforcement is not a necessary condition (Experiments II and III) or even a sufficient condition (Experiment I) for the occurrence of behavioral contrast. On the other hand, the same data suggest that reduction in response rate in one component of a multiple schedule is sufficient to produce positive behavioral contrast in the other.

A recent study (Wilke, 1971) suggests that neither a reduction in frequency of reinforcement nor a decrease in rate of responding are necessary conditions for the emergence of positive behavioral contrast. Three rats and one pigeon were placed on multiple schedules of food reinforcement. For the rats, random-interval 25-second (RI25-second) schedules were programmed in both components while VI1 schedules were programmed in both components of the multiple schedule for the pigeon. An RI schedule is similar to a VI schedule except that the reinforcers are assigned in a truly random fashion. Reinforcement for both species was immediate during baseline training. Following the attainment of stable performance in both components, delayed reinforcement was introduced into one of the components. For the rats, this meant that the dipper was lowered into the milk reservoir and held there 5 seconds before being raised (during baseline, the dipper had been lowered into the milk and raised immediately). For the pigeon, delayed reinforcement meant that the key was darkened for 3 seconds before the food hopper was raised and remained dark during reinforcement. During baseline, the key was darkened only during reinforcement. Reinforcement in the unchanged component continued to be delivered without delay for both species. Results showed that for the rats, corrected response rates (not including the delay period) in the changed component did not decline, relative to baseline rates. The pigeon showed a transitory decline in corrected response rate in the changed component but when the delay was shortened from 5 to 3 seconds the rate returned to a level comparable with the rate during baseline. Similarily, reinforcement frequencies did not decline in the changed component, relative to baseline frequencies, for the pigeon and one of the rats, and declined only slightly (about 2%) for the other two rats. In spite of this, a substantial positive behavioral contrast effect was observed in the unchanged component for all four Ss. Wilke suggests that the introduction of a "less-preferred" condition into one component of a multiple schedule may be a sufficient condition for the production of positive behavioral contrast. In a similar analysis, Bloomfield (1969) had earlier suggested that a "worsening of conditions" might be a sufficient condition for behavioral contrast.

Premack (1969), on the other hand, has pointed out that a less-preferred situation is not a sufficient condition for behavioral contrast. Terrace (1966b) has shown: (a) that when a discrimination was acquired without errors (S never responded in the presence of the negative stimulus), contrast did not appear in the presence of the positive (reinforced) stimulus; and (b) following exposure to MULT (VI1-EXT), such that response rate fell to zero in the EXT component, contrast was observed to disappear. Premack points out that the nonreinforced stimulus in an errorless discrimination or the extinction component in a well practiced MULT (VI-EXT) schedule would still be less preferred even though no contrast is present. Premack suggests, on the other hand, that contrast results if and only if there is a change in the aversiveness associated with one of the components in the schedule. He adds that such an aversive condition may lead to emotional respondes (frustration) which in turn may produce positive behavioral contrast. Thus Premack believes a change in aversiveness to be the necessary and sufficient condition for behavioral contrast.

Summary. Thus, it may be tentatively concluded that at both the observational and explanatory levels, positive behavioral and the PRAE may be related. At the observational level, both phenomena are characterized by a facilitation of responding. In the case of the PRAE, this is accomplished by introducing a lower frequency of reinforcement (partial reinforcement) into a discrete-trial responding situation. In the case of positive behavioral contrast, response facilitation in the presence of one stimulus may be caused in a variety of ways, including the introduction of a lower frequency of reinforcement in the presence of a second stimulus. At the explanatory level, both the PRAE (Spence, 1960) and positive behavioral contrast (Terrace, 1966b) have been attributed to the elicitation of emotional responses by nonreinforcement.

Purpose of the Present Research

As indicated in the preceding sections of the General Introduction, when running speed is measured in the discrete-trial runway situation, a PRAE often emerges. That is, during early acquisition, partial reinforcement leads to inferior performance, relative to continuous reinforcement, but at asymptote, partial reinforcement produces faster running speeds than continuous reinforcement. Furthermore, when the effects of consummatory time are controlled for, a similar effect frequently emerges when asymptotic responding is measured in the free-operant Skinner box situation. When operant responding is measured in a discrete-trial Skinner box situation, on the other hand, partial reinforcement usually leads to inferior performance, relative to continuous reinforcement, throughout acquisition.

The discrepancy between the discrete-trial runway situation and the analagous discrete-trial Skinner-box situation points to the possible importance of response topography in determining the effect of partial reinforcement on behavior since this is the primary difference between the two situations. Similarily, the discrepancy between the discrete-trial and free-operant situations suggests that intertrial interval duration may be an important variable to consider since this is the only factor distinguishing these two response situations. As mentioned in the Summary of the section dealing with discrete-trial Skinner-box situations, strain of rat may also be a variable which determines the effect of partial reinforcement on acquisition performance.

The present research was carried out in an attempt to further clarify the discrepancy between the effect of partial reinforcement on the discrete-trial lever-pressing response, on the one hand, and the discrete-trial running response and the free-operant lever-pressing response, on the other hand. To this end, particular attention was directed toward the characteristics of the response, strain of rat and intertrial interval duration.

EXPERIMENT I

A number of experiments employing a discrete-trial lever-pressing response were reviewed in the General Introduction. Only one of these, (Porter and Hug, 1965a) obtained a PRAE in which partial reinforcement led to inferior performance, relative to continuous reinforcement, in early acquisition, but produced superior performance at asymptote. As a result, a replication of this study was deemed necessary. The present experiment was identical to that carried out by Porter and Hug (1965a) except that in the present study, albino rats of the Wistar strain rather than hooded rats of the Long-Evans strain were used. In addition, the intertrial interval in the present experiment was 15 seconds whereas it had been 30 seconds in the former study. Finally, in the present study, rats were run under food deprivation for a sweetened condensed milk reinforcer. Porter and Hug (1965a), on the other hand, deprived their rats of water and used a water reinforcer.

Method

Subjects

Sixteen male albino rats of the Wistar strain, 120 days old at the start of the experiment, served as Ss and were maintained at 80% of their free-feeding body weights. A control group of rats (N=4) was maintained on ad lib food in order to periodically estimate the weight gain due to growth. The 80% weights of the experimental Ss were adjusted twice to allow for this growth factor.

Apparatus

The training apparatus was a Skinner box (Lehigh Valley Electronics, Model 1417) with dual retractable levers and a dipper which dispensed 0.1 ml of a 52% (by weight) solution of Nestles sweetened condensed milk in water. A frosted cue light (0.4 foot candles) was located over the lever. The box was enclosed in a sound-insulated, ventilated chamber and was located in a separate room from the programming equipment. All latencies and response times were recorded on running time meters (Lehigh Valley Electronics, Model 1306A).

Procedure

Following magazine training, a lever-pressing response was shaped to the left lever and each S received 100 reinforcers on CRF (the right lever remained inaccesible to S throughout the experiment). Reinforcement consisted of a 5-second access to the dipper and the left cue light was illuminated during reinforcement. On the following day, the response requirement was raised to FR2 and each S received 50 reinforcers in a free-responding situation. At this point, a discrete-trial procedure was initiated. Following each FR unit, defined as a trial, the lever was retracted for 15 seconds during which time responding was impossible. Each S received 24 such discrete trials daily throughout acquisition. On Day 3, each trial consisted of 3 lever-pressing responses and this requirement was raised to FR5 on the fourth day.

On Day 5, Ss were divided into two groups (N=8) and partial reinforcement training was initiated. The experimental group (Group 50) was placed on a 50% reinforcement schedule in which a random half of the daily trials were nonreinforced. The complete sequence of reinforced and nonreinforced trials during each daily session for Group 50 appears in Table 1 of the Appendix. The control group (Group 100) continued to receive reinforcement on every trial. The response requirement on this first day of partial reinforcement training remained at FR5. On Days 6 and 7, the response requirement was further increased to FR8 and finally to FR10 on the eighth day of training. All Ss received 24 trials per day for 15 days with the response requirement at FR10.

During each daily session, two dependent variables were recorded: (1) cumulative latency; and (2) cumulative response time. In this study, the latency measure was the time from the start of lever insertion until the first lever press, while the response time measure was the elapsed time from the first lever press until the tenth. Both latencies and response times were cumulated over the last 22 daily trials for each S. The first two trials in each session were not recorded to allow for warm-up effects. Since latencies and response times tend to be positively skewed (Winer, 1962) these data were converted to logarithms before statistical analysis.

Results

The results of acquisition training are presented in Figures

1 and 2. The figures show that during the 15 days of training on FR10, Group 50 had both longer latencies and longer response times than Group 100. Even after 15 days with 24 trials per day there was no apparent convergence of the curves.

These differences were tested for significance by means of separate 2 x 15 analyses of variance (Winer, 1962). The Percent Reinforcement factor in both analyses was a between-*S*s factor with two levels (100% or 50% reinforcement) while the Days factor was a within-*S*s factor with 15 levels (days 8-22). The analysis of latencies produced a significant Percent Reinforcement factor (F (1,13)=17.65, $p<.05$). This was interpreted to mean that *S*s receiving 50% reinforcement showed significantly longer lever-pressing latencies than *S*s receiving 100% reinforcement. Neither the Days factor nor the Percent Reinforcement x Days interaction was significant at the .05 level. The response time measure also yielded a significant Percent Reinforcement factor (F (1,13)=17.76, $p<.05$). This was interpreted to mean that *S*s receiving 50% reinforcement responded slower during the FR10 chain than *S*s receiving 100% reinforcement. In addition, the response time data showed a significant Days factor (F (14,82)=9.64, $p<.05$) which was understood to mean that *S*s, irrespective of group, showed a decrease in response time during acquisition. As in the first analysis, the Percent Reinforcement x Days interaction was not significant at the .05 level.

Figure 1. Mean log cumulative latency as a function of percentage reinforcement and days in Experiment I.

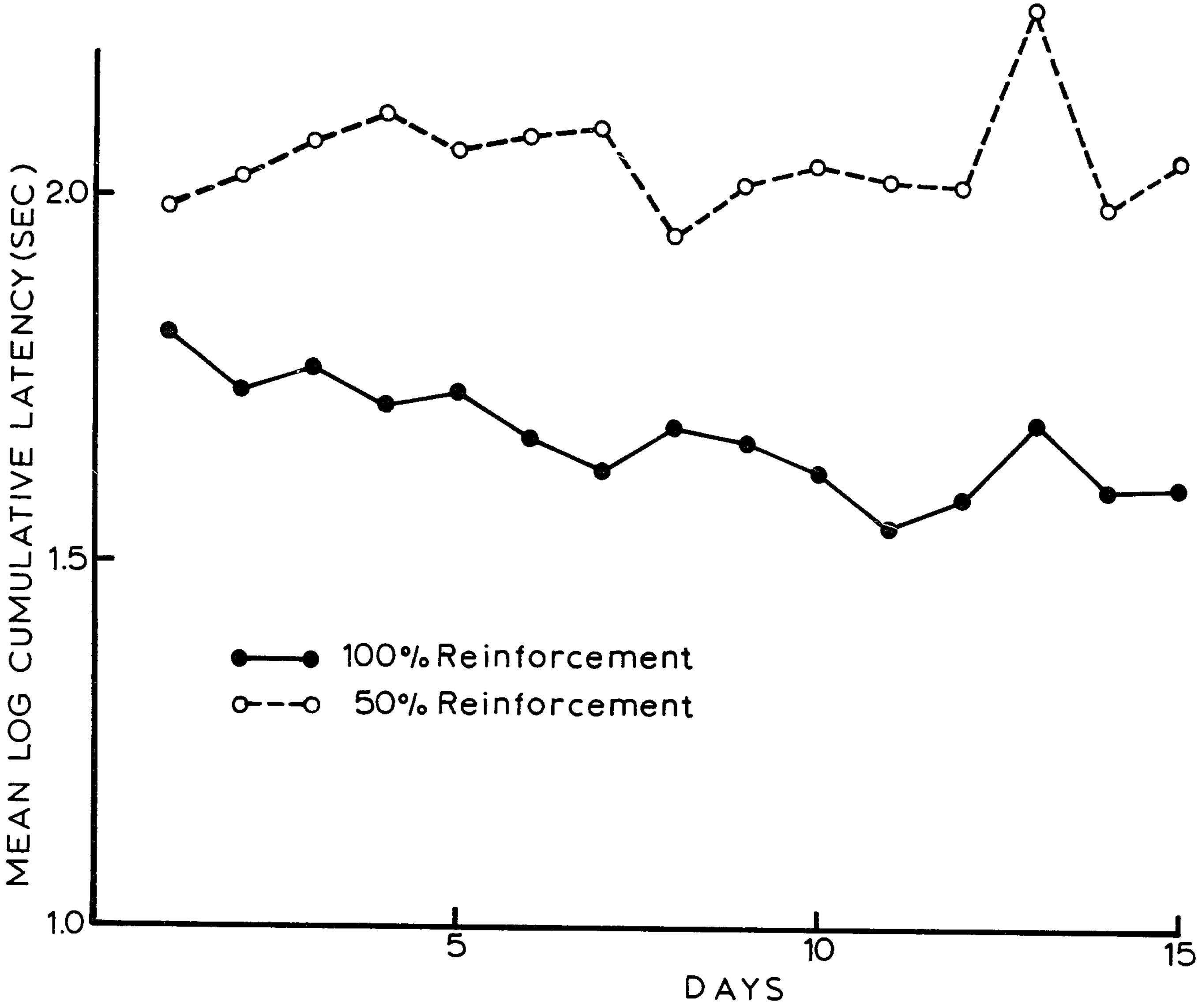
MEAN LOG CUMULATIVE LATENCY (SEC)
2.0
1.5
1.0
5
10
15
DAYS
100% Reinforcement
50% Reinforcement

Figure 1

Figure 2. Mean log cumulative response time as a function of percentage reinforcement and days in Experiment I.

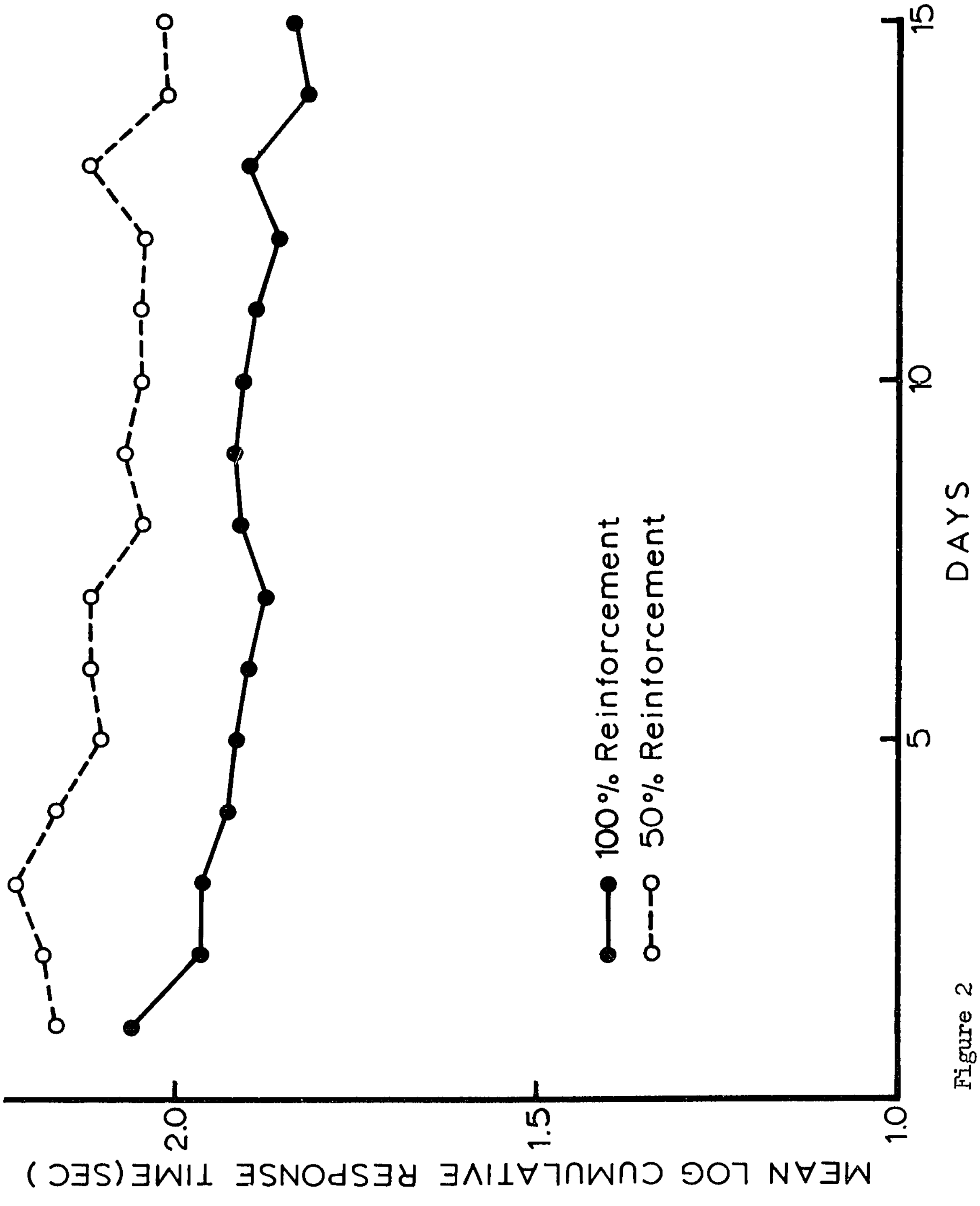
MEAN LOG CUMULATIVE RESPONSE TIME(SEC)
2.0
1.5
1.0
5
10
15
DAYS
100% Reinforcement
50% Reinforcement

Figure 2

Further analysis (Hays, 1963) revealed that the assumption of homogeneity of variance of latencies (F_{Max} $(7,2)=3.1$, $p > .05$) and response times (F_{Max} $(7,2)=2.0$, $p > .05$) was justified. Complete summary tables for both analyses of variance used in this experiment appear in Tables 2 and 3 of the Appendix.

Discussion

The results of Experiment I do not agree with those obtained by Porter and Hug (1965a). Even after 360 trials, Group 50 still exhibited longer latencies and response times than Group 100. In the study carried out by Porter and Hug (1965a), rats receiving 50% reinforcement demonstrated faster overall response speeds on trials 85-96 than those receiving 100% reinforcement. On the other hand, these results are in agreement with a number of other studies employing a discrete-trial lever-pressing situation (Marx, 1967; 1969; Porter and Kopp, 1967; Tombaugh, McCloskey and Tombaugh, 1971; Uhl and Young, 1967; Zimmerman, 1960). The results of these latter studies, like those of the present experiment, indicate that in a discrete-trial lever-pressing situation, partial reinforcement leads to inferior performance, relative to continuous reinforcement, throughout acquisition. This is often not the case in the discrete-trial runway situation or free-operant lever-pressing situation wherein partial reinforcement frequently leads to superior performance, relative to continuous reinforcement, at asymptote.

EXPERIMENT II

Spence (1960) stated that the elicitation of competing responses by conditioned frustration in a partial reinforcement situation leads to inferior performance initially, and that the asymptotic superiority of partial over continuous reinforcement occurs only after these competing responses have disappeared. It could be hypothesized that in the first experiment, competing responses had not been eliminated after 360 trials, and as a result, the performance of Group 50 was still inferior to that exhibited by Group 100. Thus, it might be that these data are quantitatively but not qualitatively different from those often found in the runway.

Accordingly, a second experiment was designed in which a large amount of pretraining under conditions of 100% reinforcement of FR10 responses was given before partial reinforcement was introduced. This training, it was reasoned, might be expected to eliminate many competing responses before any nonreinforcement occurred. That is, the competing responses referred to by Spence (1960) must be responses which are already within the response repertoire of the organism. In the discrete-trial lever-pressing situation, such responses might include biting the lever and leaving the lever to check the dipper. Under conditions of 100% reinforcement of FR10 lever pressing, such competing responses should eventually disappear so that following the onset of each trial, S moves rapidly toward the lever and presses it 10 times without stopping. Thus, when partial reinforcement is introduced into the situation, following such pretraining under conditions of 100% reinforcement, these competing responses should be low in the response hierarchy of the organism and hence less available for elicitation by r_F-s_F than in Experiment I in which extensive pretraining was not administered.

Method

Subjects

Twenty male albino rats of the Wistar strain, 200 days old at the beginning of the experiment, served as Ss. They were maintained at 80% of their free-feeding weights. A control group of rats (N=5) was maintained on ad lib food in order to periodically estimate the gain due to growth. The 80% weights of the experimental rats were adjusted once to allow for this growth factor.

Apparatus

The equipment employed in this experiment was identical to that reported in the first study except that two identical Skinner boxes (Lehigh Valley Electronics, Model 1417) were used instead of only one.

Procedure

Phase I. Following magazine training, a lever-pressing response was shaped to the left hand lever (the right lever remained inaccessible throughout training) and each S obtained 100 reinforcers on a CRF schedule. The following day, the response requirement was raised to FR5 and a discrete-trial procedure was instituted such that each FR5 response produced a reinforcer and resulted in a 15-second lever retraction. Ss received 20 such trials daily during the remainder of the experiment. The response requirement remained at FR5 the following day but was further increased to FR10 on Day 4 of training. With the response requirement held at FR10, a further 29 days of training were administered and both cumulative latencies and cumulative response times were recorded. As in Experiment I, cumulative latency was the time from lever insertion until the first lever press, cumulated over the 20 daily trials, while cumulative response time was the time from the first lever press until the tenth, cumulated over the daily trials. No nonrecorded warm-up trials were administered in the present experiment.

Phase II. At this stage, responding appeared to be asymptotic and a matching procedure was used to form four groups (N=5). Mean cumulative response times summed over the last 30 days of training in Phase I were computed for each S. Using these data, Ss were ranked from fastest to slowest and divided into 5 blocks of 4 Ss each. In forming each experimental group, one S was drawn at random from each of the 5 blocks with the added restriction that no more than 2 Ss in each group could be either the fastest or slowest S in each block.

Group 100, the control group, continued to receive reinforcement on every trial as in Phase I. A second group (Group 70) received reinforcement on a random 70% of the daily trials while a third group (Group 50) was reinforced on a random 50% of the daily trials during Phase II. Finally, a fourth group (Group 30) received reinforcement on only a random 30% of the daily trials. The complete sequences of reinforced and nonreinforced trials during each daily session for Groups 70, 50 and 30 appear in Table 4 of the Appendix. As in Phase I, cumulative latencies and cumulative response times were recorded daily and these measures were converted to logarithms for purposes of statistical analysis.

Results

A test for homogeneity of variance (Hays, 1963) revealed that the variances of log cumulative response times for Groups 100, 70, 50 and 30 did not differ significantly (F_{Max} (4,4)=5.2, $p > .05$). On the other hand, the same test showed that the variances of log cumulative latencies were not homogeneous (F_{Max} (4,4)= 22.4, $p < .05$). Inspection of the variances revealed that the cell variance for Group 30 (.157) was much larger than those of Groups 100, 70 and 50 (.007, .029 and .033, respectively). When the data of Group 30 were omitted, the assumption of homogeneity of variance was met (F_{Max} (4,3)=4.7, $p > .05$). Accordingly, Group 30 was omitted from the analysis of variance of latencies but included in a similar analysis of response times.

Latencies were analyzed by means of a 3 x 30 analysis of variance in which the Percentage Reinforcement factor was a between-Ss factor with 3 levels (100%, 70% or 50% reinforcement). On the other hand, response times were analyzed in a 4 x 30 analysis of variance. In this analysis the Percentage Reinforcement factor was a between-*S*s factor with 4 levels (100%, 70%, 50% or 30% reinforcement). In both analyses, the Days factor was a within-*S*s factor with 30 levels (days 1-30 of Phase II.). The analysis of mean log cumulative latencies yielded only a significant Percent Reinforcement factor (F $(2,12)=11.40$, $p<.05$). Further analysis (Winer, 1962) revealed that Groups 100 and 70 did not differ significantly but that both showed shorter latencies than Group 50. No other factors, however, reached statistical significance at the .05 level. The analysis of log cumulative response times, on the other hand, produced both a significant Percentage Reinforcement factor (F $(3,16)=35.93$, $p<.05$) and a significant Days factor (F $(29,464)=2.34$, $p<.05$), as well as a significant Percentage Reinforcement x Days interaction (F $(87,464)=4.31$, $p<.05$). Further analysis (Winer, 1962) revealed that while Group 30 demonstrated longer response times than both Groups 70 and 50, no other group differences emerged. The significant Days factor was interpreted to mean that response times declined over days in Phase II. The main source of the Percentage Reinforcement x Days interaction appeared to be Groups 100 and 50. From the data, it appeared that while Group 50 demonstrated longer response times than Group 100 during the first half of Phase II, this situation reversed during the latter half with Group 50 showing shorter response times than Group 100.

In order to facilitate comparison with Experiment I and provide further clarification of these data, a 2 x 30 analysis of variance (Winer, 1962) was carried out on the data obtained during Phase II from Groups 100 and 50. These data appear in Figures 3 and 4. The Percentage Reinforcement factor was a between-Ss factor with two levels (100% or 50% reinforcement) and the Days factor was a within-Ss factor with 30 levels (days 1-30 of Phase II). The analysis of log cumulative latencies yielded a significant Percentage Reinforcement factor (F (1,8)=30.61, $p <$ .05) with 50% reinforcement leading to longer latencies than 100% reinforcement. A similar analysis of log cumulative response times, however, failed to yield a significant Percentage Reinforcement factor but did produce a significant Days factor (F (29,232)=3.36, $p < .05$) as well as a significant Percentage Reinforcement x Days interaction (F (29,232)=1.90, $p < .05$). Inspection of the response time data shown in Figure 4 revealed that Group 50 demonstrated slower response times early in Phase II, but that on Day 18 of Phase II, Group 50 crossed over and continued to respond faster than Group 100 (except on Day 21) until the end of training. This was reflected by the significant Percentage Reinforcement x Days interaction and presumably accounts for the lack of a significant main effect of Percentage Reinforcement.

A t test (Winer, 1962) revealed that over Days 1-15 of Phase II, Group 50 responded significantly slower than Group 100

Figure 3. Mean log cumulative latency as a function of percentage reinforcement and days in Experiment II.

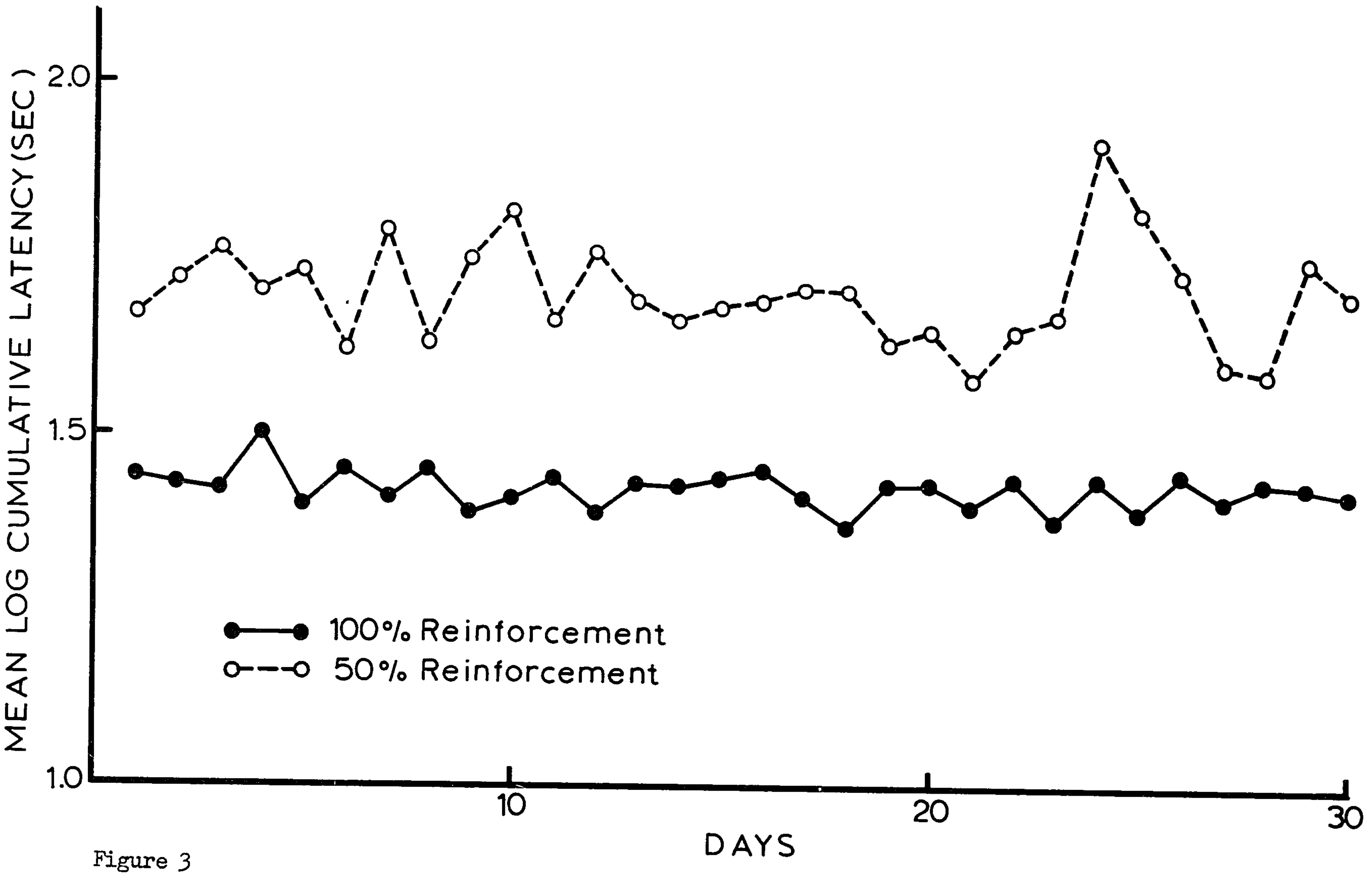
MEAN LOG CUMULATIVE LATENCY (SEC)
2.0
1.5
1.0
10
20
30
DAYS
100% Reinforcement
50% Reinforcement

Figure 3

Figure 4. Mean log cumulative response time as a function of percentage reinforcement and days in Experiment II.

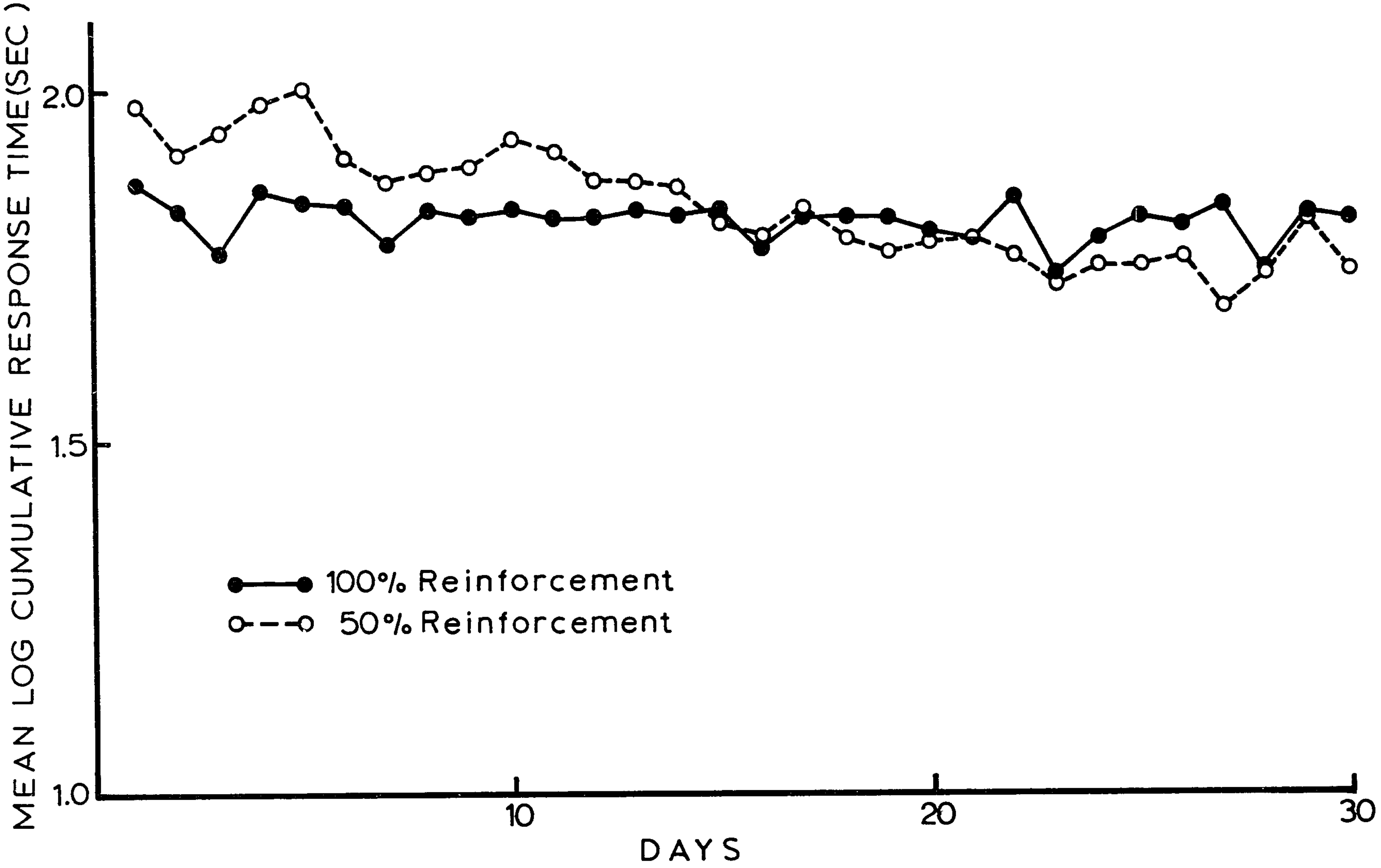
MEAN LOG CUMULATIVE RESPONSE TIME(SEC)
2.0
1.5
1.0
10
20
30
DAYS
100% Reinforcement
50% Reinforcement

Figure 4

($\underline{t}$ (8)=3.8, $\underline{p}<.05$). A similar $\underline{t}$ test revealed, however, that over Days 16-30 of Phase II, Group 100 and Group 50 did not differ ($\underline{t}$ (8)=0.4, $\underline{p}>.05$).

Complete summary tables for the analyses of variance employed in this experiment appear in Tables 5-7 of the Appendix.

Discussion

While Group 50 did not demonstrate significantly faster response times than Group 100 over the last 15 days of Experiment II, the data were in the direction predicted by Spence (1960). Perhaps if more Ss had been used, thus increasing the power of the F test, this difference would have proved significant. It might be pointed out that the typical runway study employs a much larger number of Ss than were used in the present study. In any case, the large decrement due to partial reinforcement which was observed in Experiment I disappeared after extensive training in Experiment II. These results taken together seem to provide at least tentative support for Spence's frustration-competing response analysis of the PRAE. The fact that the extensive training in Experiment II failed to reduce latencies in Group 50 is not contradictory. Since Ss were never observed to leave the dipper during the 5-second reinforcement period, it follows that after nonreinforced trials, Ss in Group 50 were less likely to be in the vicinity of the lever when it began to extend than Ss in Group 100 on a comparable trial.

Seligman (1970) has introduced the concept of "response preparedness" which may be relevant to this discussion. Seligman has argued that responses like the running response can be termed "prepared" in the rat while those like the lever-pressing response are "unprepared". This implies, according to Seligman, that there is a "built-in" biological tendency to associate running with the acquisition of food but that this is less true of the lever-pressing response. It follows that the running response will be acquired rapidly for food reinforcement while the lever-pressing response will be learned only slowly for the same reinforcer. Furthermore, the gradual acquisition of a lever-pressing response may be associated with the presence of persistent competing responses.

Experience may also play a role in the development of skillfully performed responses. While the running response is a behavior high in the response repertoire of the rat and has probably been practiced before the organism ever sees the runway, this is not true of the lever-pressing response. Since this response has a low operant level, careful shaping and a good deal of practice are required before it is performed easily. Thus, more competing responses might be expected in the early stages of the acquisition of a lever-pressing response, and more trials may be needed to demonstrate the PRAE.

These data provide tentative support for the conclusion that the runway and discrete-trial Skinner box situations are not fundamentally different when partial and continuous reinforcement are compared. Observed differences in these response situations may be of a quantitative rather than a qualitative nature. While, according to Spence (1960), competing responses drop out quickly when running is partially reinforced, it seems probable that competing responses are more persistent under conditions of partial reinforcement of lever-pressing. Thus, in the discrete-trial Skinner box analogue of the runway, the eventual superior performance under conditions of partial as compared with continuous reinforcement predicted by Amsel's frustration theory, can be expected to emerge only after extensive training.

EXPERIMENT III

It was hypothesized that the failure to obtain a statistically significant PRAE even after extensive training in Experiment II might reflect a ceiling effect. In other words, since FR schedules generate very high rates of responding, it might have been physically impossible for Ss in Group 50 to respond faster than those in Group 100. Experiment III was designed to test this hypothesis in an attempt to facilitate FR10 responding using a behavioral contrast paradigm. The behavioral contrast paradigm was selected because, as indicated in the General Introduction, positive behavioral contrast, like the PRAE, is a facilitation of responding. Furthermore, both the PRAE (Spence, 1960) and positive behavioral contrast (Terrace, 1966b) have been identified as motivational phenomena, attributable to the same underlying factor - emotional responses produced as a consequence of responding in the presence of nonreinforcement. Only two previous investigators have attempted to produce behavioral contrast in an FR schedule.

As outlined in the General Introduction, Reynolds (1961b) demonstrated that FR pause times decreased and overall FR response rate (including pause time) increased in a MULT (FR150-VI) schedule as the frequency of reinforcement in the VI component was reduced from 40 reinforcers per hour to 0 reinforcers per hour.

Another study which investigated behavioral contrast in FR schedules was carried out by Bloomfield (1967a). Response rates during a series of FRs (FR10, FR20, FR50, FR100, FR200, and FR 500) presented in isolation were compared with rates on the same FR schedules paired with a VI1 component in a MULT (VI1-FR) schedule. Results showed that when the FR was small (FR10, FR20 or FR50), FR response rate was higher when the FR was paired with VI1 than when it was presented alone. In an attempt to account for this, Bloomfield noted that the reinforcement frequency in an FR10, FR20 or FR50 schedule was much higher than the reinforcement frequency on VI1 and consequently, the relative rate of reinforcement associated with FR in MULT (VI1-FR) exceeded 0.5, where no contrast would be expected. On the other hand, the data also revealed that when the FR requirement was larger (FR100, FR200 or FR500) the FR response rate was higher when FR was presented in isolation than when it was paired with VI1. Again using a relative frequency of reinforcement analysis, Bloomfield pointed out that the reinforcement frequency associated with FR100, FR200 or FR500 was lower than the reinforcement frequency in VI1 and as a result, the relative frequency of reinforcement associated with the FR component of the MULT (VI1-FR) schedule was less than 0.5, the point at which contrast would not be expected. Thus FR response rate was found to be directly proportional to the relative frequency of reinforcement associated with FR.

While it appears from these data that behavioral contrast can be produced in an FR schedule using pigeons, no data exist which demonstrate FR contrast in the albino rat. Accordingly, the following experiment was designed in an attempt to facilitate FR10 responding by changing a MULT (FR10-VI30 second) schedule to a MULT (FR10-EXT) schedule. Based on the results obtained by Reynolds (1961b) and Bloomfield (1967a), a decrease in pause time and an increase in local FR response rate (behavioral contrast) concomitant with a decrease in response rate during EXT, might be expected. The ceiling hypothesis, on the other hand, predicts a decline in FR pause time (behavioral contrast) but no further increase in FR local response rate due to the physiological limitations of the organism.

Method

Subjects

In the first of two studies, three male albino rats of the Wistar strain (A, B and C), approximately 180 days old at the start of the experiment, were maintained at 80% of their free-feeding body weights. In the second experiment, three naive male albino rats of the Wistar strain (D, E and F), also 180 days old at the start of the experiment, were maintained at 80% of their free-feeding weights.

Apparatus

Training was carried out in a Grason-Stadler Skinner box (model E3124B-100) which delivered .045 gm Noyes food pellets as reinforcers. A cue light (0.4 foot candles) was located slightly above and to the right of the lever. The box was enclosed in a sound attenuating chamber and was located in a separate room from the programming equipment. All E controlled events were handled by standard programming equipment.

Procedure

In the initial phase of the first study, Ss were trained on a MULT (FR10-VI30 second) schedule of reinforcement. The house light was illuminated during the FR10 component and remained off during the VI30 component. Completion of a single FR10 delivered a reinforcer and switched the schedule to VI30. The VI30 component remained in effect for one minute, at the end of which, the schedule was automatically switched back to FR10. This cycle was repeated 30 times a day for each S.

Two dependent variables were recorded during each FR10 throughout training. Cumulative FR pause time was the time from the onset of the cue light until the first lever press, cumulated over the 30 daily cycles. Cumulative FR response time was the elapsed time from the occurrence of the first lever press until the tenth, cumulated over the 30 daily cycles. Cumulative FR pause time was converted to mean FR pause time (cumulative FR pause time/30) and cumulative FR response time was converted to mean FR local response rate (cumulative FR responses/cumulative FR response time) each day for purposes of data presentation. In addition, one dependent variable was recorded during each VI30 throughout training. Cumulative VI responses was the number of responses made during each one-minute presentation of VI30, cumulated over the 30 daily cycles. This variable was converted to mean VI response rate (cumulative VI responses/30) each day.

For each S, when mean FR local response rate reached a stable baseline (i.e., did not systematically increase or decrease during five successive sessions), the schedule was changed to MULT (FR10-EXT). There was also a 10-second change-over-delay (COD) utilized at the end of each EXT component to prevent the chance reinforcement of responding during the EXT component by the onset of the FR component (which was associated with a high rate of food reinforcement). This meant that after one minute, the schedule was not switched from EXT to FR10 until an additional 10 seconds had elapsed, during which, no lever press occurred. Thus the minimum time spent in EXT during each cycle was 70 seconds. The dependent variable, cumulative VI responses, recorded during baseline training, became cumulative EXT responses following the change from MULT (FR10-VI30) to MULT (FR10-EXT). This variable was converted to mean EXT response rate (cumulative EXT responses/ total time, including COD, spent in EXT during each daily session). Following the change from MULT (FR10-VI30) to MULT (FR10-EXT) for each S, an additional 20 days of training were administered.

The second study was a replication carried out using three new rats (D, E and F).

Results

Contrary to prediction, following the change from MULT (FR10-VI30) to MULT (FR10-EXT), a systematic decline in mean FR local response rate was observed in both studies. At the same time, responding in the EXT component declined from a mean VI response rate of 51 responses per minute during baseline to an overall mean EXT response rate of 6 responses per minute during the last block of five sessions on MULT (FR10-EXT). Mean FR local response rates for all six rats appear in Figure 5. Inspection of these data revealed that mean FR local response rates, calculated in blocks of five days, declined during the 20 days immediately following the change in schedule, for four of the six rats. On the other hand, A demonstrated virtually no change in mean FR local response rate while E showed little change, followed by a substantial increase in this measure during the last five days on MULT (FR10-EXT).

In addition, following the change from MULT (FR10-VI30) to MULT (FR10-EXT), all six Ss showed a large increase in mean FR pause time. These data, calculated in blocks of five days, appear in Figure 6.

Discussion

The data obtained in the present experiment do not agree with the findings of Reynolds (1961b) or Bloomfield (1967a) since behavioral contrast did not emerge. Furthermore, the results do not support the ceiling hypothesis since FR local response

Figure 5. Mean FR local response rates calculated in blocks of five days in a MULT (FR10-VI30-second) schedule (BL) and in a MULT (FR10-EXT) schedule (C_1, C_2, C_3 and C_4) for *S*s *A*, *B*, *C*, *D*, *E* and *F* in Experiment III.

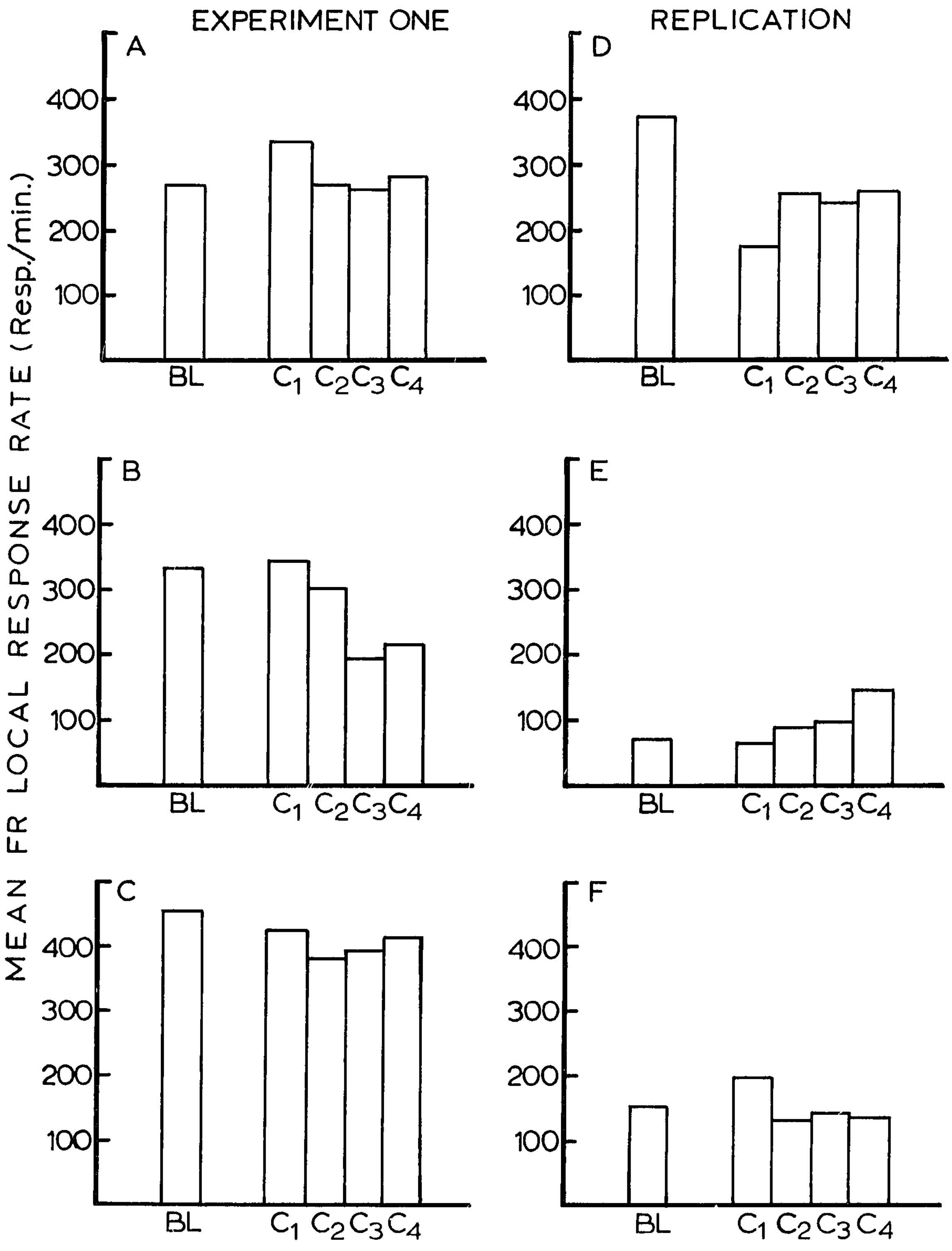
EXPERIMENT ONE
REPLICATION
MEAN FR LOCAL RESPONSE RATE (Resp./min.)
A
B
C
D
E
F
400
300
200
100
BL
C1 C2 C3 C4

Figure 5

Figure 6. Mean FR pause times calculated in blocks of five days in a MULT (FR10-VI30-second) schedule (BL) and in a MULT (FR10-EXT) schedule (C_1, C_2, C_3 and C_4) for _S_s _A_, _B_, _C_, _D_, _E_ and _F_ in Experiment III.

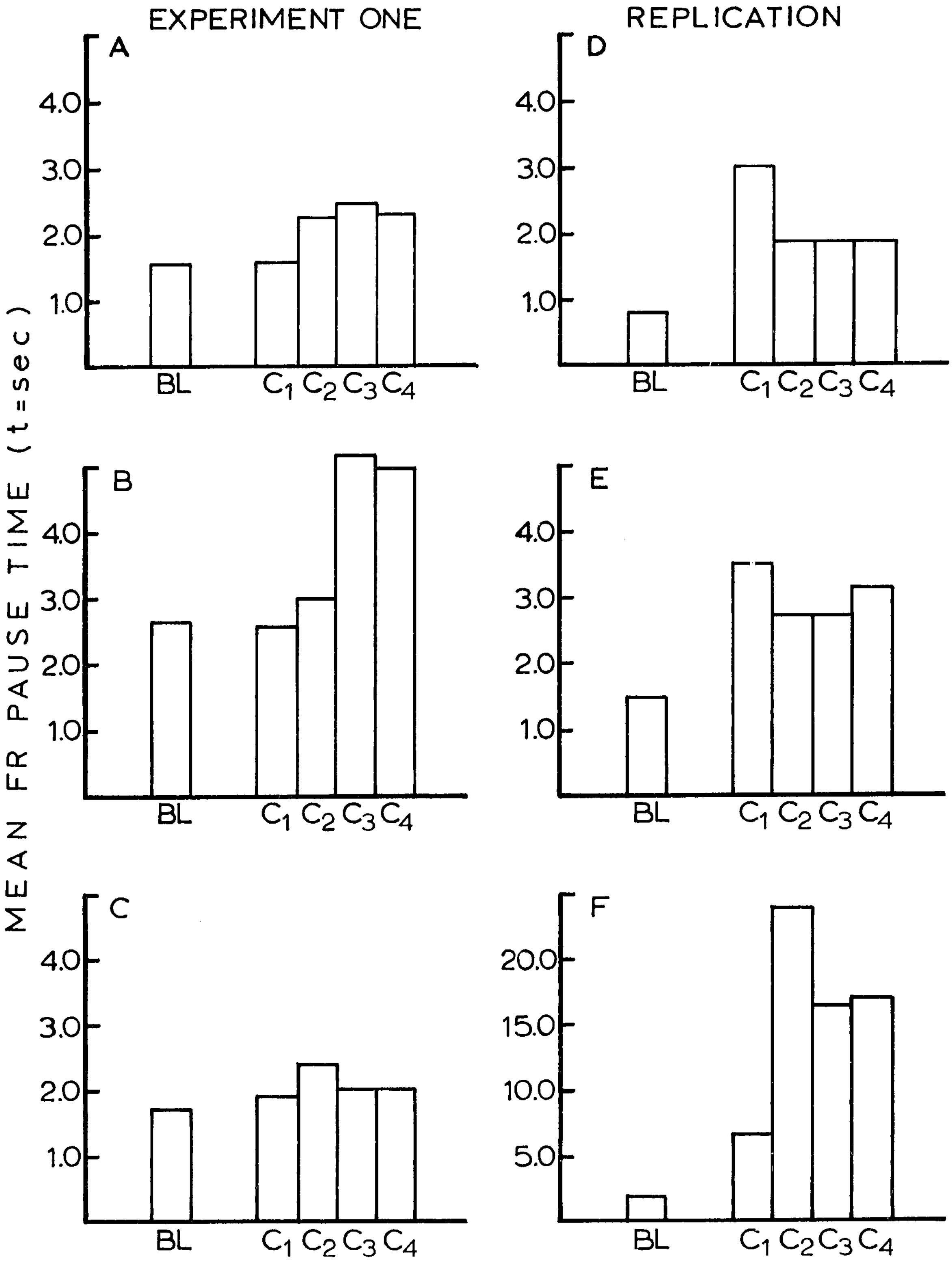
EXPERIMENT ONE
REPLICATION
MEAN FR PAUSE TIME (t=sec)
A
4.0
3.0
2.0
1.0
BL
C1 C2 C3 C4
D
4.0
3.0
2.0
1.0
BL
C1 C2 C3 C4
B
4.0
3.0
2.0
1.0
BL
C1 C2 C3 C4
E
4.0
3.0
2.0
1.0
BL
C1 C2 C3 C4
C
4.0
3.0
2.0
1.0
BL
C1 C2 C3 C4
F
20.0
15.0
10.0
5.0
BL
C1 C2 C3 C4

Figure 6

rate declined instead of remaining unchanged. This latter finding suggests that some additional factor was operating in the present experiment which was not present in the studies performed by Reynolds (1961b) and Bloomfield (1967a). A difference in procedure between the present experiment and most studies of behavioral contrast suggest that this factor might be TO punishment. While the change from one component of the multiple schedule to another is response independent in the usual study of behavioral contrast, only the change from VI30 (or EXT) to FR10 was response independent in the present experiment. The change from FR10 to VI30 (or EXT), on the other hand, was response produced. That is, when the cue light was on, 10 lever presses produced not only reinforcement but access to the other component as well. When the schedule was MULT (FR10-VI30) this meant that FR responding produced a component with a lower, but nonetheless greater than zero, frequency of reinforcement. On the other hand, when the schedule was MULT (FR10-EXT), responding in the FR component produced a one-minute TO during which the frequency of reinforcement was zero.

Azrin and Holtz (1966) have defined a punisher as any stimulus condition, contingent on a response, which reduces the future probability of that response. Thus, when electric shock is made contingent on responding and the rate of responding declines, the response is said to have been punished. Since mean FR pause time increased and mean FR local response rate declined in the present experiment, punishment of FR behavior by TO can be inferred. It should be noted, however, that while pause times may have increased due to punishment by TO, it is also possible that these increases are a function of the previous, rather than the impending period of TO. The use of a 10-second COD ensured that S was not responding on the lever when the MULT (FR10-EXT) schedule changed from EXT to FR10. As a result, S was usually not in the vicinity of the lever when the cue light was illuminated. When the schedule was MULT (FR10-VI30), on the other hand, Ss were responding on the lever when the schedule was switched from VI30 to FR10. As a result, longer latencies would be expected in the former case due to what will be termed the displacement function of TO and a punishment interpretation is unnecessary. This is not the case in the response time measure, on the other hand, since recording of this measure does not begin until S has made the first lever press in each FR10. Further discussion of the punishing effects of TO and electric shock will be reserved until the Introduction to Experiment IV.

A TO punisher was not involved in the experiment carried out by Bloomfield (1967a) since Bloomfield never paired FR with TO but instead compared behavior generated by an FR schedule presented in isolation with that produced by FR in a MULT (FR-VI1) schedule. While Reynolds (1961b), using a single pigeon, paired FR150 with EXT, he did so for only 150 cycles of the multiple schedule compared with 600 cycles in the present study.

During the remainder of the sessions, FR produced access to a VI schedule in which the frequency of reinforcement was greater than zero. It is possible that a more prolonged period of exposure to MULT (FR150-EXT) would have resulted in a decline in FR response rate in that study as well. It is interesting to note that in the present experiment, reductions in mean FR local response rate were observed in only three rats (C, D and E) during the first five days of exposure to MULT (FR10-EXT). On the other hand, the three remaining rats (A, B and F) showed transitory behavioral contrast during the first five days (150 cycles) following the change from MULT (FR10-VI30) to MULT (FR10-EXT).

The results of the experiments performed by Reynolds (1961b) and Bloomfield (1967a) suggest that behavioral contrast can be produced using pigeons on an FR schedule and that the failure in the present study was due to the presence of TO punishment. As a result, the results of the present experiment permit neither acceptance nor rejection of the ceiling effect hypothesis. Thus, it may be that the failure to obtain a significant PRAE in Experiment II resulted from the inability of the Ss in Group 50 to respond faster than those in Group 100 due to physiological limitations. These data do suggest, on the other hand, that TO punishment may have been a factor in Experiments I and II, a possibility which will be examined in the next experiment.

EXPERIMENT IV

As indicated in the General Introduction, there is some evidence that an effect similar to the PRAE can occur in the free-operant situation. Unfortunately, few investigators have controlled for the interaction between response rate and consummatory time. Only the studies of Jenkins, McFann and Clayton (1951), Skinner (1938) and Zeiler (1972) adequately demonstrated that responding on a partial reinforcement schedule was superior to that produced by continuous reinforcement. Neuringer and Chung (1967) also controlled for the effects of consummatory time but found that FI local response rate declined when 100% reinforcement of FI responses was changed to 15% reinforcement. In any case, there has not been any study designed to compare continuous and partial reinforcement of an FR response in the free-operant situation.

The only difference between the discrete-trial situation investigated in Experiments I and II, and a free-operant situation, is the intertrial interval during which the lever is retracted. As suggested in the Discussion of Experiment III, there is some evidence, including the results of Experiment III, that an intertrial interval in an operant situation can act as a response-produced TO, punishing the behavior which produces it.

In addition, Kaufman and Baron (1968) have carried out a study which further clarifies the punishing effects of response-produced TO on behavior. Rats were trained in a lever-pressing situation and interresponse times (IRTs) were compared when three responses (the first two reinforced and the third not reinforced) produced a 2-minute TO during which reinforcement was unavailable. The results showed that following introduction of this TO, the R_2-R_3 IRT increased substantially. It is important to note that this behavior reduced the overall rate of reinforcement and demonstrates that TO can act as a punisher. Leitenberg (1965) has pointed out the problems involved in demonstrating the aversiveness of TO. For example, a number of studies have demonstrated that passive avoidance will occur in the presence of a discriminative stimulus when such behavior leads to avoidance of TO. That is, _S_s will avoid making a response when responding leads to TO. These results may be explained without recourse to the aversiveness of TO, however, since the avoidance behavior leads to a higher overall frequency of reinforcement. A second study showed that as the duration of TO was increased through 10, 60, 90 and 120 seconds, the R_2-R_3 IRT increased as well. In a third study, on the other hand, reinforcing R_3 with food was found to eliminate the punishment effect since the R_2-R_3 IRT returned to the no-TO baseline. The results of these studies suggest that the punishing effects of TO on behavior may be especially evident when the behavior is partially, rather than continuously, reinforced.

Ferster and Skinner (1957) have also provided data relevant to this hypothesis. In a within-_S_s study, pause times increased and local FR response rates decreased in a discrete-trial FR schedule when the percentage of reinforced ratios was decreased. In addition, however, decelerated response rates were observed toward the end of each FR run when percentage reinforcement of FR60 ratios was reduced to 25% for the first pigeon and percentage reinforcement of FR 30 ratios was reduced to 15% for the second bird. These investigators attributed this to the punishment provided by the 3-minute TO which was produced by the last key peck in each FR run. This suggests that response-produced TO may indeed punish FR responding when the FR runs are partially rather than continuously reinforced.

In a related study, Dardano and Sauerbrunn (1964) used pigeons to investigate the effect of response-contingent electric shock on FR performance. Results showed that when the 50th key peck in an FR50 led to a .05-second shock of varying intensity as well as food reinforcement, low intensity shock (3.0 ma) produced no effect on performance, relative to a no-shock baseline but high intensity shock (6.2, 9.4 or 12.6 ma) led to marked performance changes. These disruptions included pauses, local rate changes and occasionally, decelerations at the end of the ratio. Overall response rates tended to be depressed, relative to the no-shock baselines.

These data suggest that if reinforcement is omitted on 50% of the FR runs in a free-operant situation (i.e., one in which there is no response-produced ITI to punish FR responding), superior performance, relative to 100% reinforcement of FR runs, should result within relatively few trials. That is, without TO punishment present, the motivating effects of partial reinforcement may become evident in performance.

Finally, the data obtained by Porter and Hug (1965a) in the only clear demonstration of a PRAE in the discrete-trial lever-pressing situation, suggest that strain of rat may be an important factor in determining whether the effects of partial reinforcement on lever-pressing behavior are facilitating or inhibiting. Porter and Hug, using hooded rats of the Long-Evans strain, obtained a PRAE within 100 trials while Experiment I in the present research, using albino rats of the Wistar strain, failed to produce a PRAE after 360 trials of training.

Accordingly, the following experiment was designed to investigate the effects of strain (hooded or albino rats), intertrial interval duration (15 or 0 seconds), and percentage reinforcement (100% or 50%) on the performance of a homogeneous chain of lever presses. Based on the results of previous research, the following predictions were made. A main effect of ITI duration was expected with longer response times occurring when the ITI was 15 seconds as compared with 0 seconds. If the ITI in a discrete-trial lever-pressing situation is a TO punisher, Ss responding to produce reinforcement and a 15-second ITI should respond more slowly than Ss whose behavior produces reinforcement but no ITI. In addition, a significant ITI x Percentage Reinforcement interaction was predicted: (1) based on the findings of Kaufman and Baron (1968) and Ferster and Skinner (1957) that TO punishes partially reinforced behavior more than continuously reinforced behavior, 50% reinforcement was expected to lead to slower asymptotic response times than 100% reinforcement when the ITI was 15 seconds; and (2) based on the findings by Jenkins, McFann and Clayton (1951), Skinner (1938) and Zeiler (1972) that in the free-operant situation partial reinforcement leads to performance superior to that produced by continuous reinforcement, 100% reinforcement was expected to lead to slower asymptotic response times than 50% reinforcement when the ITI was 0 seconds. Finally, a significant Percent Reinforcement x ITI x Strain interaction was predicted with a PRAE occurring within the 400 trials of acquisition for hooded rats, but not for albino rats, when the ITI duration was 15 seconds. This prediction was based on the results of Experiment I in the present research in which no PRAE was obtained using albino rats of the Wistar strain, and those of Porter and Hug (1965a) in which a PRAE was obtained in fewer trials using hooded rats of the Long-Evans strain.

It was also decided to sound a loud buzzer following the 10th lever press on each trial in the present experiment. On reinforced trials, this buzzer was sounded throughout the 5-second reinforcement event. On nonreinforced trials, the buzzer was also sounded for 5 seconds but the dipper was not raised. The intention was to make the reinforcement (or nonreinforcement) event as discriminable as possible in the hope that this would result in the rapid elimination of competing responses (e.g., leaving the lever to check the dipper before the 10th lever press).

Method

Subjects

Twenty-four naive male albino rats of the Wistar strain and 24 naive male hooded rats of the Long-Evans strain, 150-175 gm at the start of the experiment, were reduced to 80% of their free-feeding weights. Control groups of both strains were maintained on ad lib food in order to periodically estimate the gain due to growth. The 80% weights of all Ss were twice adjusted to allow for this growth factor.

Apparatus

Two Skinner boxes (Lehigh Valley Electronics, Model 1417) with dual retractable levers and a dipper that dispensed 0.1 gm of a 52% (by weight) solution of Nestles sweetened condensed milk in water, were used. In addition, a 6-volt buzzer was mounted on the dipper frame of each Skinner box. The sound pressure level (SPL) of this buzzer was measured using a Type 2203 Precision Sound Level Meter in conjunction with a Type 1613 Octave Filter Set (Bruel and Kjaer, Denmark). With the reference level set at 0.0002 dynes/square centimeter and equal weight given to all frequencies, the measured SPL was 92 dB. All experimenter-controlled events and data recordings were handled by standard programming equipment.

Procedure

Each S was given two successive 15-minute sessions of magazine training on Days 1 and 2 of training. During this time the levers were retracted and the dipper was presented for 5 seconds at random intervals (mean=30 seconds). During the second session, all Ss were observed to drink regularily from the dipper.

Beginning on Day 3, a lever press was shaped to the left lever for each S in turn (the right lever remained retracted throughout the experiment). This shaping procedure took four days during which a lever press was successfully shaped for all 48 Ss.

The following day, Ss in each strain were randomly assigned to four groups (N=6) resulting in a total of eight groups. For purposes of identification, each of these groups was assigned a label which consisted of a letter followed by two numbers. The letter in each label designates strain (albino rats are represented by A while the hooded rats are identified by the letter H). The first number in each label, on the other hand, designates intertrial interval duration in seconds (15 or 0) and the second number denotes percentage reinforcement (100 or 50). In addition, all Ss were allowed to obtain 100 reinforcers on a CRF schedule. Odd numbered rats (three per group) were assigned to Box 1 and even numbered rats to Box 2. On Day 8, a further 100 reinforcers were delivered to each S on a CRF schedule but during each 5-second reinforcement period, the buzzer was sounded.

The next day, the response requirement was raised to FR5 and a discrete trial procedure was introduced for Ss assigned to Groups A-15-100, A-15-50, H-15-100 and H-15-50. For Ss in these groups, the lever was retracted for 20 seconds following the completion of each FR5. Since reinforcement duration was 5 seconds, the intertrial interval was actually 15 seconds, timed from the termination of reinforcement, for these four groups. For Ss in the remaining four groups (Groups A-0-100, A-0-50, H-0-100 and H-0-50), the lever was also retracted momentarily following each FR5 but was immediately reintroduced back into the box. The total time required for this operation was about 4.0 seconds. As a result, the intertrial interval was approximately 0 seconds, timed from the termination of reinforcement. Finally, Groups A-15-50, A-0-50, H-15-50 and H-0-50 were placed on a 50% reinforcement schedule such that only a random half of the ratios produced a reinforcer. The sequence of reinforced and nonreinforced trials was the same one used in the first two experiments and appears in Table 8 of the Appendix. On nonreinforced trials for these four groups, the fifth lever press caused the lever to retract for 0 or 15 seconds and the buzzer to sound for 5 seconds. On the other hand, Ss in Groups A-15-100, A-0-100, H-15-100 and H-0-100 remained on a 100% reinforcement schedule of FR5 responses. For Ss in these four groups, the completion of each FR5 caused the dipper to be raised for 5 seconds, the buzzer to sound for 5 seconds and the lever to retract for either 15 or 0 seconds. All 48 Ss received 20 trials under these conditions on Day 9 and the procedure was repeated on Day 10. The following day, the response requirement was raised to FR10 but conditions were otherwise unaltered and since no further changes were made in procedure, Day 11 was the first day of training proper. Training was continued for an additional 19 days at which time the experiment was terminated. Throughout the 20 days of training, Ss were run in a different random order during each of three successive days. A summary of conditions under which each of the groups were run during the last 20 days of the experiment appears in Table 9 of the Appendix.

Two dependent variables were recorded for each S during Days 11 to 30: (1) cumulative response time during lever-presses 1-6 of the FR10 response unit; and (2) cumulative response time during lever-presses 6-10 of the FR10 response unit. Cumulative response time during lever-presses 1-6 was the elapsed time from the first lever-press until the sixth, cumulated over the 20 daily trials for each S. Cumulative response time during lever-presses 6-10 was the elapsed time from the sixth lever-press until the tenth, cumulated over the 20 daily trials for each S. Latencies were not recorded in this experiment due to the possible interaction between the punishing and displacement effects that TO may have on this dependent variable.

Results

Since, in previous experiments, cumulative response time during lever-presses 1-10 of each FR10 response was the dependent variable, the two measures in this experiment were summed daily for each S to yield this overall measure. Also, as in the previous studies, all three measures were converted to logarithms for purposes of statistical analysis.

A 2 x 2 x 2 x 20 analysis of variance (Winer, 1962) of log cumulative response times during lever-presses 1-10 was carried out. The Strain factor (Wistar or Long-Evans rats), the Intertrial Interval factor (15 or 0 seconds) and the Percent Reinforcement factor (100 or 50 percent reinforcement) were all between-Ss factors. The Days factor, on the other hand, was a within-Ss factor with 20 levels (days 11-30). This analysis yielded a significant Intertrial Interval effect (F (1,40)=29.87, $p<.05$) which resulted from the fact that cumulative response times during lever-presses 1-10 were longer when the intertrial interval was 0 seconds than when it was 15 seconds. These data appear in Figure 7. The only other significant factor to emerge from this analysis was the Days factor (F (19,760)=129.6, $p<.05$), indicating that cumulative response times during lever-presses 1-10 decreased throughout training. The Percent Reinforcement factor was not significant, however, nor did percentage reinforcement interact significantly with any other factor. Figure 8 shows that 50% reinforcement led to slightly, but not significantly, slower response times during lever-presses 1-10 than 100% reinforcement, throughout training. In order to facilitate comparison

Figure 7. Mean log cumulative response time during lever-presses 1-10 as a function of intertrial interval duration and days in Experiment IV.

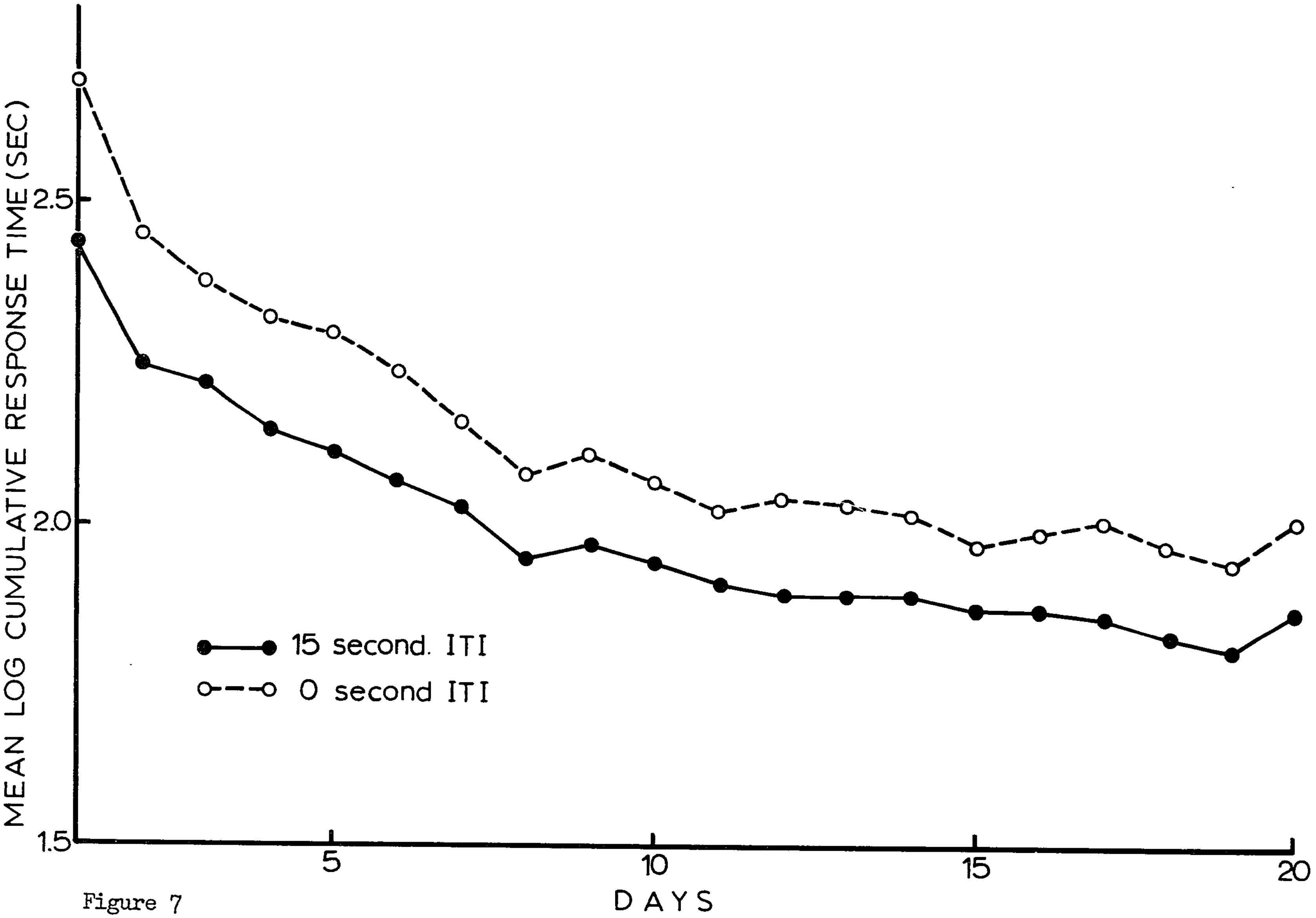
MEAN LOG CUMULATIVE RESPONSE TIME (SEC)
2.5
2.0
1.5
5
10
15
20
DAYS
15 second. ITI
0 second ITI

Figure 7

Figure 8. Mean log cumulative response time during lever-presses 1-10 as a function of percentage reinforcement and days in Experiment IV.

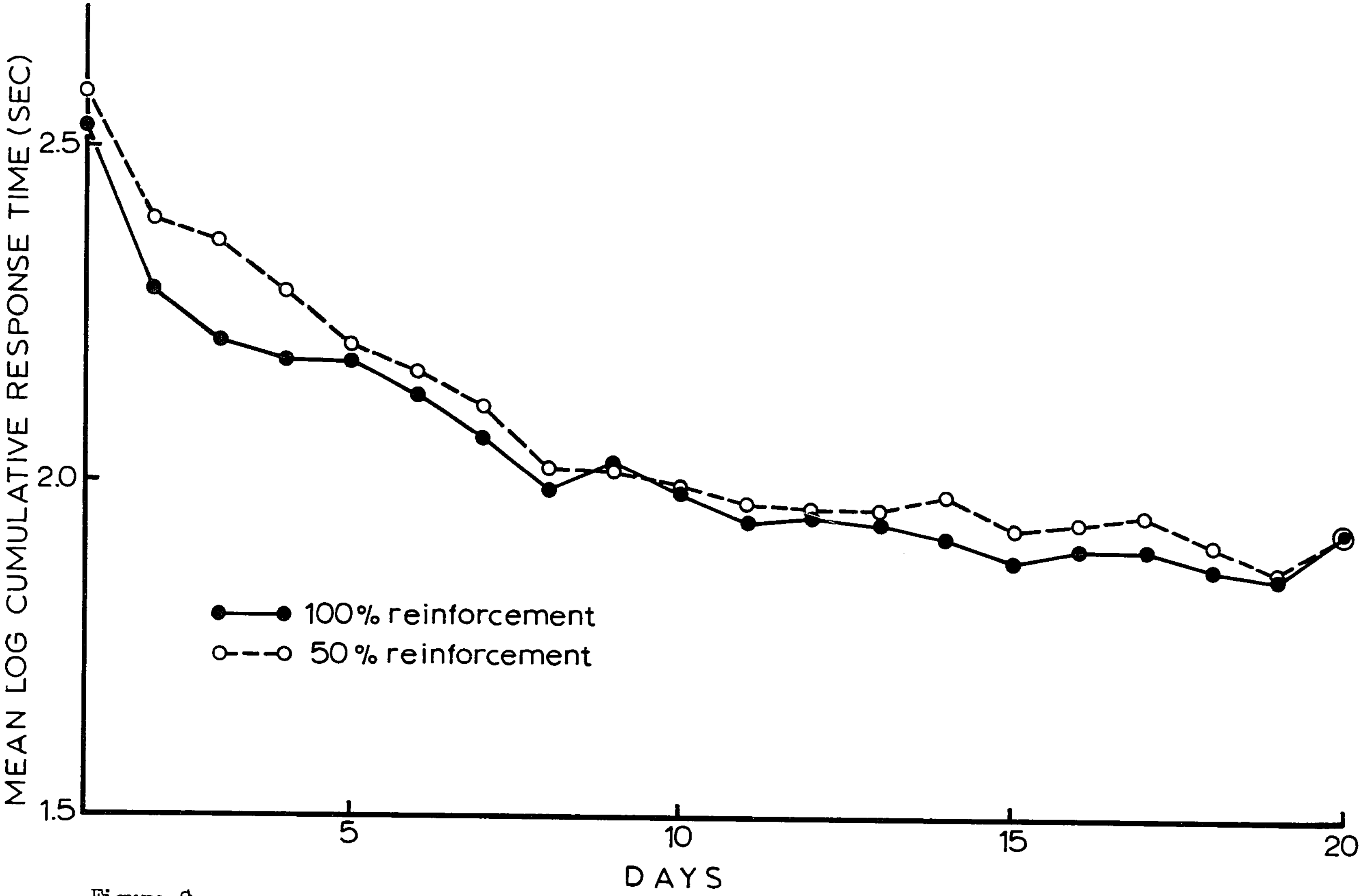
MEAN LOG CUMULATIVE RESPONSE TIME (SEC)
2.5
2.0
1.5
5
10
15
20
DAYS
●—● 100% reinforcement
○- - -○ 50% reinforcement

Figure 8

with Experiment I, the data from Groups A-15-100 and A-15-50 are presented in Figure 9. Except for the presence of the buzzer, these groups are identical to Groups 100 and 50 in Experiment I. Clearly, however, the data presented in Figure 9 are quite different from those obtained in Experiment I with 50% reinforcement leading to slightly, but not significantly, faster response times than 100% reinforcement, throughout training.

Identical analyses of variance were performed on log cumulative response times during lever-presses 1-6 and log cumulative response times during lever-presses 6-10. As with the previous dependent variable, both these analyses yielded only significant Intertrial Interval and significant Days effects.

A test for homogeneity of variance (Hays, 1962) revealed that cell variances of log cumulative response times during lever-presses 1-10 did not differ significantly (F_{Max} $(5,8)=1.9$, $p > .05$). Similar tests carried out on log cumulative response times during lever-presses 1-6 (F_{Max} $(5,8)=2.2$, $p > .05$) and log cumulative response times during lever-presses 6-10 (F_{Max} $(5,8)=1.7$, $p > .05$) also demonstrated homogeneity of variance.

Since the FR ratio was broken into two parts for purposes of data recording in this experiment, it was also possible to compare performance during lever-presses 1-6 with that during lever-presses 6-10. Because the first six lever-presses of an FR10 are separated by five interresponse intervals while the last four lever presses involve only four, the mean interresponse

Figure 9. Mean log cumulative response time during lever-presses 1-10 as a function of percentage reinforcement and days for Groups A-15-100 and A-15-50 in Experiment IV.

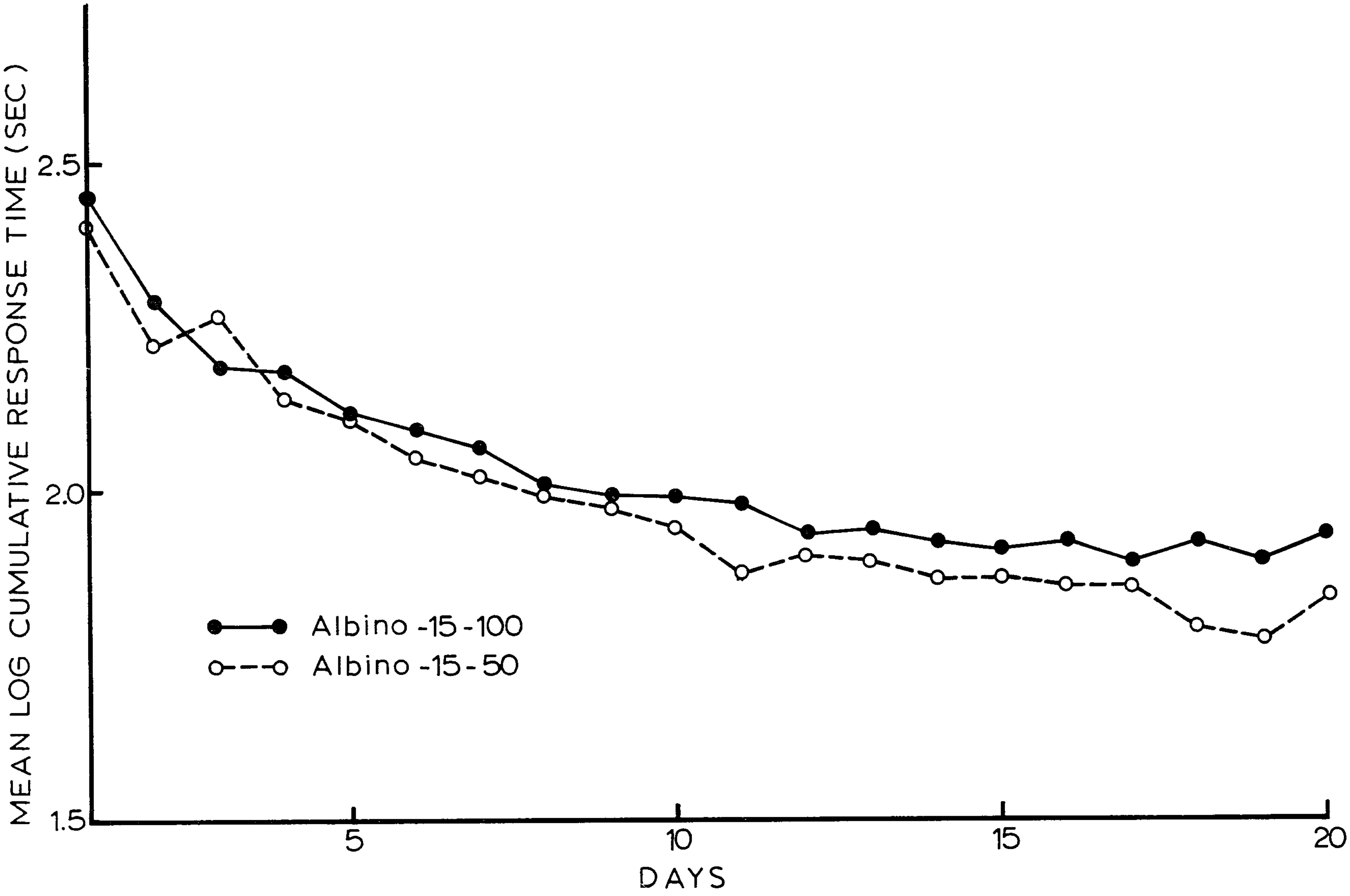
MEAN LOG CUMULATIVE RESPONSE TIME (SEC)
2.5
2.0
1.5
5
10
15
20
DAYS
● Albino -15-100
○ Albino -15-50

Figure 9

time (IRT) was calculated for each portion to permit comparison. These data were analyzed by means of a 2 x 2 x 2 x 2 analysis of variance (Winer, 1962). Both the Strain factor (Wistar or Long-Evans rats) and the Intertrial Interval factor (15 or 0 seconds) were between-*S*s factors with two levels. The Percentage Reinforcement factor was also a between-*S*s factor with two levels (100% or 50% reinforcement) while the Ratio Portion factor was a within-*S*s factor, also with two levels (lever-presses 1-6 or lever-presses 6-10 of each FR response unit). As expected, based on the results of the analysis of log cumulative response times during lever-presses 1-10, this analysis yielded a significant Intertrial Interval effect (F (1,40)=30.15, $p<.05$) with the 0-second ITI leading to longer mean IRTs than the 15-second ITI. In addition, however, the Ratio Portion factor was significant (F (1,40)=20.76, $p<.05$) with mean IRT almost 0.1 seconds shorter during lever-presses 6-10 than during lever-presses 1-6. Finally, the analysis yielded a significant Intertrial Interval x Ratio Portion interaction (F (1,40)=4.80, $p<.05$).

In order to further clarify the source of the interaction, a Newman-Keuls post hoc analysis (Winer, 1962) was carried out. The results of this test revealed that while the mean IRT recorded during lever-presses 1-6 was shorter when ITI was 15 seconds than 0 seconds (F (1,13)=13.0, $p<.05$), no such difference emerged when mean IRTs during lever-presses 6-10 were compared at the two levels of ITI. In addition, the post hoc analysis showed that when ITI was 0 seconds, mean IRT recorded during lever-presses 6-10 was shorter than mean IRT during lever-presses 1-6 ($\underline{F}$ (1,10)= 4.96, $\underline{p}<.05$). No such difference emerged, however, when mean IRTs recorded during the two segments of the FR chain were compared at the 15-second ITI. These data appear in Figure 10.

As in the case of the main analyses, a test for homogeneity of variance (Hays, 1963) revealed no difference between cell variances ($\underline{F}_{Max}$ (5,16)=8.7, $\underline{p}>.05$).

In summary, the analyses of mean log cumulative response times revealed only significant Intertrial Interval and Days effects. The significantly inferior performance produced by 50% reinforcement in Experiment I did not emerge in the present study, even during very early acquisition. In addition, an analysis revealed that mean IRTs were longer during lever-presses 1-6 than lever-presses 6-10 of the FR10 response unit. Further analysis revealed that this was true when the ITI was 0 seconds but not when the ITI was 15 seconds.

Summary tables for the various analyses of variance employed in this experiment appear in Tables 10 to 13 of the Appendix.

Discussion

It had been predicted that the 15-second intertrial interval would yield longer response times than the 0-second ITI due to the punishing effects of TO. Instead, the reverse occurred with the 15-second ITI leading to shorter response times. Distributed practice has been shown to lead to superior performance than

Figure 10. Mean interresponse time as a function of ratio portion and intertrial interval duration in Experiment IV.

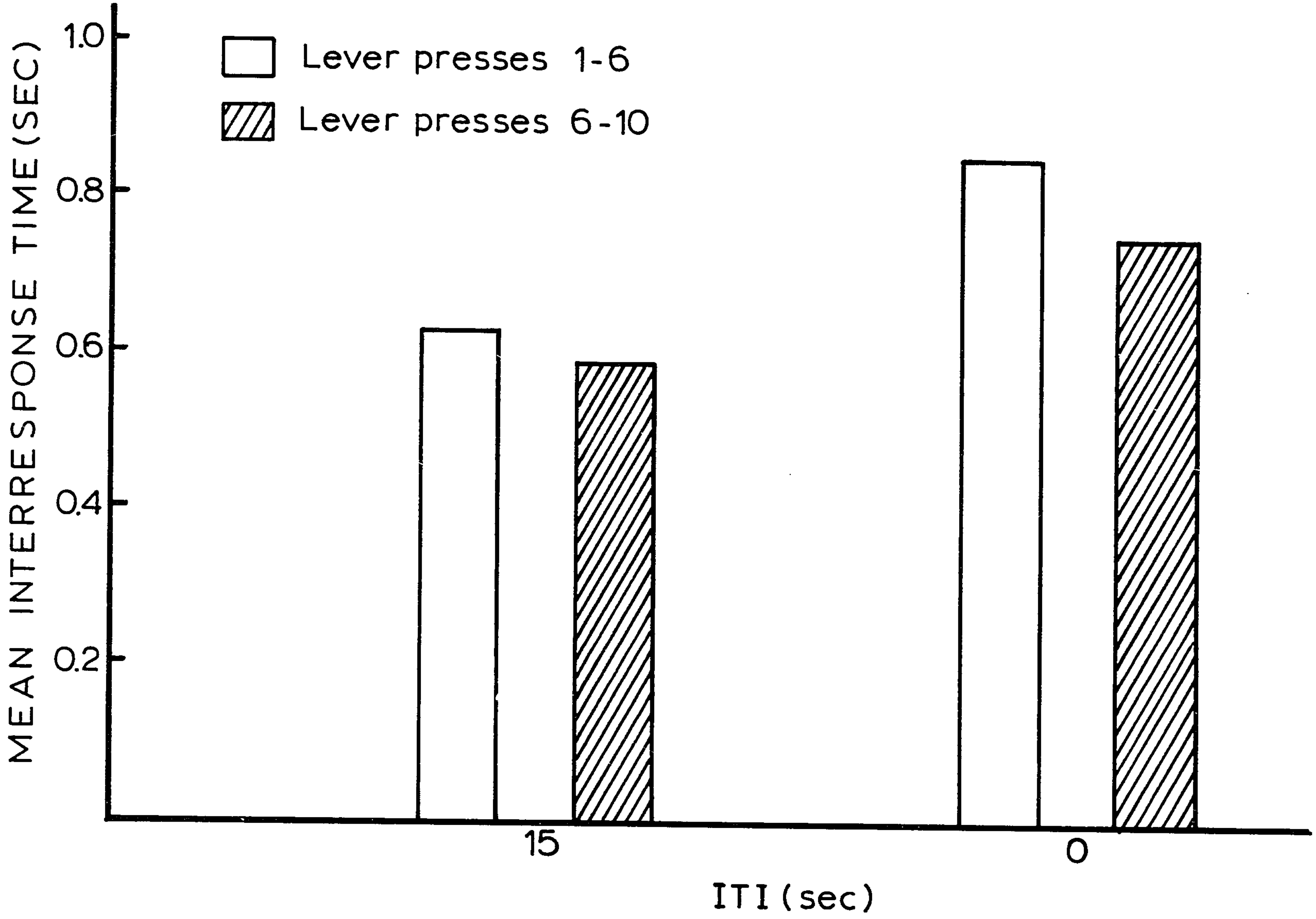
MEAN INTERRESPONSE TIME (SEC)
1.0
0.8
0.6
0.4
0.2
Lever presses 1-6
Lever presses 6-10
15
0
ITI (sec)

Figure 10

massed practice in a variety of experiments (Kientzle, 1946; Spence and Norris, 1950; Wolach, 1971). The latter experiment employed a discrete-trial Skinner box situation in which the response was a single lever press. According to Wagner (1959), it is possible that inhibition generated by responding as well as inhibition provided by reinforcement on trial n serves to slow down performance on trial n+1. Furthermore, it is possible that this inhibition dissipates with time and as a result, affects performance less when the ITI is 15 seconds than when it is 0 seconds. It can also be assumed that inhibition generated on trial n would affect performance more during the first part of trial n+1 than the latter part, regardless of ITI duration. This assumption is supported by the IRT data which revealed longer IRTs during lever-presses 1-6 than 6-10. In addition, mean IRTs were longer during lever-presses 1-6 than lever-presses 6-10 when the ITI was 0 seconds but not when the ITI was 15 seconds, providing further support for the inhibition explanation.

The predicted interaction between percentage reinforcement and intertrial interval, with 50% reinforcement leading to faster response times than 100% reinforcement when the intertrial interval was 0 seconds and the reverse when the duration of the ITI was 15 seconds, also failed to emerge. Thus, the hypothesis that the intertrial interval acts as a response-produced TO, suppressing partially reinforced responding more than continuously reinforced behavior, received no support in this experiment. Perhaps if the ITI had been longer or the percentage reinforcement lower, a punishment effect might have been obtained. The data from Experiment III, as well as the findings of Ferster and Skinner (1957) provide support for this conclusion.

One interesting finding, however, did emerge in this study. Experiment II showed that in a discrete-trial lever-pressing situation, extensive training was required to increase the performance of a partially reinforced chain of lever presses to the level produced by the continuous reinforcement of such responses. Previously, data from Experiment I had demonstrated that even after 360 trials, performance in the partially reinforced group was clearly inferior to that observed in the continuously reinforced group. In the present experiment, however, as Figure 8 shows, this difference did not appear during acquisition as evidenced by the lack of a significant percentage reinforcement factor. In fact, inspection of the data obtained from the two groups of albino rats exposed to a 15-second ITI (i.e., A-15-100 and A-15-50), which appear in Figure 9, showed that throughout training, partial reinforcement led to slightly shorter response times than continuous reinforcement although this difference was not significant. In Experiment II, on the other hand, Group 50 which was identical to Group A-15-50, did not surpass Group 100, which was identical to Group A-15-100, during the first 940 trials of training. The only difference between Groups 100 and 50 in Experiment II and Groups A-15-100 and A-15-50 in the present experiment, was the presence of the 5-second buzzer immediately following each block of 10 lever presses in the latter.

The discussion of the inferior performance generated by partial reinforcement in the first two experiments suggested the presence of persistent competing responses interfering with the performance of the partially reinforced response. One of these competing responses might be that of approaching the dipper during the performance of the response chain (Platt and Spence, 1967). Dipper approaches prior to the completion of the ratio would, of course, result in extended response times. In the present experiment, the buzzer was included to make the reinforcement (or nonreinforcement) event more discriminable in the hope that this would result in the rapid elimination of premature dipper approaches. According to Spence (1960), once such competing responses are eliminated, the motivating effect of nonreinforcement should become evident in performance and partially reinforced organisms should respond more vigorously than those on a continuous reinforcement schedule. Unfortunately, this did not occur in the present experiment, although, it is interesting to note that when Groups A-15-100 and A-15-50 are compared, the results are in the predicted direction.

Elimination of competing responses by a powerful discriminative stimulus is only one possible explanation of these data. Kelleher and Gollub (1962) have stated that a stimulus repeatedly presented just before a primary reinforcer (food) can acquire conditioned reinforcing properties. Since the buzzer employed in the present experiment was sounded while the dipper was raised it is likely that it acquired conditioned reinforcing properties, thus providing reinforcement for responding on trials not terminating in primary reinforcement. As a result, better performance would be expected under conditions of partial reinforcement when trials, not primarily reinforced, terminated with a conditioned reinforcer. This conclusion is supported by data obtained by Bitgood and Platt (1971). Pigeons were reinforced either 100% or 50% of the time for responding on an FR30 schedule. The intertrial interval, during which the chamber was darkened, was 20 seconds and the light in the food hopper was illuminated on non-reinforced as well as reinforced trials. The results showed that FR local response rates did not differ for 100% and 50% reinforcement throughout acquisition. These investigators interpreted these results within a conditioned reinforcement framework. The data, as in the case of the present results, however, are also amenable to a competing response analysis.

As outlined in the General Introduction, Goodrich (1959) and Wagner (1962) showed that when running speed in the goal box region of a runway was measured, the PRAE failed to appear and 50% reinforcement produced slower speeds than 100% reinforcement at asymptote. There was, however, no indication of a similar effect in the present experiment. The analysis of log cumulative response times recorded during lever-presses 6-10 yielded the same results as a similar analysis of log cumulative response times during lever-presses 1-6.

The IRT analysis of variance which compared performance during the first and last parts of the FR chain did, however, reveal one important difference between the runway and the discrete trial Skinner box situations. Data obtained from the runway (Lobb, 1968) have revealed that organisms running for 100% reinforcement slow down as they near the end of the runway. In addition, they appear to slow down even more when reinforced only 50% of the time (Goodrich, 1959; Wagner, 1962). The results of the present experiment, on the other hand, reveal that mean IRT recorded during lever-presses 6-10 was shorter than that recorded during lever-presses 1-6. In other words, rats in the discrete-trial lever-pressing situation were observed to speed up rather than to slow down during the latter part of an FR10 ratio. In addition, ratio portion did not interact with percentage reinforcement as in the runway situation. The nature of the running response in the runway makes deceleration prior to arrival at the food cup necessary. The lever-pressing response, on the other hand, demands no such response rate attenuation prior to reinforcement. The greater deceleration observed near the food cup when running is partially reinforced has been attributed to the elicitation of strong anticipatory frustration (r_F-s_F) by runway cues which, in the goal region, are similar to goal box cues. This conditioned frustration is assumed to elicit so many competing responses that some fail to drop out, even with extended training (Lobb, 1968). An alternative explanation suggests that discriminative stimuli exist in the goal box region of the runway which permit the discrimination of nonreinforced trials, and result in slower running speeds on those trials (Robbins, Chait and Weinstock, 1968). The failure of Goodrich (1959) to find any difference in running speed on reinforced and nonreinforced trials, however, makes this latter explanation less tenable. The conditioned frustration interpretation is based on the assumption that the runway stimuli, both interoceptive and exteroceptive, resemble the goal box stimuli more in the goal box region of the alley than in the start box or stem regions. This is less true of the lever-press response, on the other hand, since the exteroceptive stimuli present when the first lever press is made are identical to those present when the last lever press occurs. Only the interoceptive muscle-produced stimuli change during the performance of the FR chain. Thus, in the lever-pressing situation, the stimulus complex present at the outset of each trial will be more like the stimulus complex during reinforcement than is the case in the runway situation. This may explain the failure in the present study to observe a Percentage Reinforcement x Ratio Portion interaction.

Furthermore, the IRT data are not consistent with the TO hypothesis tested in this study. If the response-produced ITI was a punisher, the mean IRT recorded during lever-presses 6-10 should have been longer than mean IRT during lever-presses 1-6 when the ITI was 15 seconds. Similarily, these measures should not have differed when ITI duration was 0 seconds. Clearly, this prediction was not confirmed.

Finally, it should be noted that the predicted strain difference did not emerge with Long-Evans rats showing a PRAE within relatively few trials. This makes the findings of Porter and Hug almost unique and difficult to explain. Perhaps they represent a type I error in which the null hypothesis was incorrectly rejected.

EXPERIMENT V

In Experiment IV, two major hypotheses were advanced based on a conception of the ITI in a discrete-trial lever-pressing situation as a TO punisher. These hypotheses were: (1) that a group of rats for which FR10 responding led to reinforcement and a 15-second ITI (TO) would respond more slowly than a group for which responding led to reinforcement but no ITI (i.e., no TO); and (2) that 50% reinforcement of FR10 responding would lead to slower responding than 100% reinforcement when each FR10 led to a 15-second ITI (because punishment is known to depress partially reinforced behavior more than continuously reinforced behavior), and the reverse when FR10 responding was not followed by an ITI (due to the motivating effects of partial reinforcement). Neither of these hypotheses was confirmed. The results of Experiment IV revealed faster responding when each FR10 led to a 15-second ITI than when each FR10 led to a 0-second ITI. Furthermore, Intertrial Interval Duration and Percentage Reinforcement did not interact at all. One possible reason for the failure to confirm the first of these hypotheses might be that the ITI in Experiment IV was only 15 seconds. Perhaps this ITI was not sufficiently long to punish the response which produced it.

Platt and Spence (1967) have presented data relevant to this hypothesis. They showed that reciprocal latency of a single lever press was a curvilinear function of ITI duration. The shortest latencies were observed when ITI duration was 10 seconds, with ITIs of 1, 5 and 30 seconds leading to longer latencies. These researchers, like the present investigator, noted that inhibition due to reinforcement or response-produced inhibition may explain why 1- and 5-second ITIs led to longer latencies than a 10-second ITI. Furthermore, it was pointed out that the poor performance observed when ITI was 30 seconds might be due to the displacement function of the intertrial interval. In other words, these investigators suggested that when ITI duration was 30 seconds, rats were less likely to be oriented toward the lever than when ITI duration was 1, 5 or 10 seconds. While this may be the case, it is also possible that the poor performance observed when ITI duration was 30 seconds was due to the punishing effects of TO. Unfortunately, the data do not permit a choice between these alternative explanations.

One way to separate these factors might be to measure performance during the execution of a response chain (e.g., FR10) and record response time (excluding latency) as in Experiments I-IV. As outlined in the discussion of Experiment III, recording of the response time measure does not commence until the first lever press has been made and as a result, any observed increase in the measure cannot be attributed to the displacement function of the ITI.

Taus and Hearst (1970) carried out a similar experiment in which pigeons were reinforced on a VI1 schedule of reinforcement in the presence of a vertical line projected on the response key. Five groups of birds were exposed to 75 such S+ periods, each 30 seconds long and separated by TOs of 0, 1, 5, 10 or 30 seconds duration, respectively. During these TOs, the box was in darkness and the pigeons emitted very few responses. The results showed that VI response rate was a linear increasing function of TO duration. These data do not show the U-shaped function obtained by Platt and Spence, but instead reveal the fastest response rate to occur when TO duration was 30 seconds. It should be noted, however, that this experiment was not an adequate test of the TO-punishment hypothesis since the changes from VI1 to TO were response independent. The results were interpreted within a behavioral contrast framework.

In summary, Platt and Spence concluded that a moderate ITI (10 seconds) leads to optimum performance due to dissipation of response or reinforcement inhibition, and longer ITI values result in poorer performance due to the displacement of the organism away from the lever. Of course, this latter response suppression may also be due to punishment by TO.

Therefore, these data suggest that had a longer ITI been employed in Experiment IV, in addition to the two values that were used, a curvilinear function might have emerged. It is possible that a 15-second TO was not sufficiently long to punish the response which produced it.

The following experiment was designed to investigate the effect of short, medium and long (0, 15 and 60 seconds) ITI durations on the performance of a lever-pressing response chain (FR10). Based on the results obtained by Platt and Spence (1967), it was predicted that log cumulative response time would be a nonmonotonic function of ITI duration with optimum performance occurring when ITI duration was 15 seconds. It was decided not to vary percentage reinforcement in the present experiment because there was no indication in Experiment IV that ITI interacts with percentage reinforcement.

Method

Subjects

Twenty-four naive male albino rats of the Wistar strain, 150-175 gm at the start of the experiment, were reduced to 80% of their free-feeding body weights. A control group of rats was maintained on ad lib food and water in order to periodically estimate the gain due to growth. The 80% weights of the experimental Ss were twice adjusted to allow for this growth factor.

Apparatus

Two Skinner boxes (Lehigh Valley Electronics, Model 1417) with dual retractable levers and a dipper which dispensed 0.1 ml of a 52% (by weight) solution of Nestles sweetened condensed milk in water were used. All experimenter-controlled events and data recordings were handled by standard programming equipment. The buzzer used in Experiment IV was not employed in the present experiment.

Procedure

During the first two days of training, each S was exposed to two successive 15-minute sessions of magazine training. During these periods, the levers were retracted and the dipper was raised at random intervals (mean=30 seconds) for 5 seconds. During the second session of magazine training, all Ss were observed to drink regularily from the dipper. On Day 3, a lever press was shaped to the left hand lever (the right lever remained retracted throughout training) for 12 Ss. A lever press was shaped to the same lever for the remaining 12 Ss the following day. On Day 4, all Ss were allowed to obtain 100 reinforcers on a CRF schedule of reinforcement. In addition, Ss were randomly assigned to three groups (N=8) at this time.

The following day, the schedule was increased to FR5 and a discrete-trial procedure was introduced. For all Ss, completion of the fifth lever press raised the dipper for 5 seconds and also resulted in the lever retracting. The duration of the intertrial interval, timed from the termination of reinforcement, was 60 seconds for Group 60, 15 seconds for Group 15, and 0 seconds for Group 0. All Ss received 20 trials with these conditions in effect. On Day 6, the first day of training proper, the response requirement was increased to FR10 but conditions were otherwise unaltered. Training was continued for an additional 17 days, at which time the experiment was terminated. Ss were run in a different random order during each of three successive days throughout training.

During the 18 days of training, two dependent variables were recorded: (1) cumulative response time during lever-presses 1-6 of each FR10 response unit; and (2) cumulative response time during lever-presses 6-10 of each FR10 response unit. Both measures were cumulated over the 20 daily trials for each S. Unfortunately, due to the lack of available recording devices, it was not possible to record latencies as well as response times.

Results

In order to facilitate comparison with previous experiments, the two dependent variables in this study were summed daily for each S to yield a third dependent variable—cumulative response time during lever-presses 1-10. All three dependent variables were converted to logarithms, as in the previous experiments, and each was analyzed by means of analysis of variance (Winer, 1962). In all three analyses, the Intertrial Interval factor was a between-Ss factor with three levels (60, 15 or 0 seconds) while the Days factor was a within-Ss factor with 18 levels (days 6-23). The analysis of log cumulative response times during lever-presses 1-10 yielded only a significant Days effect ($F\ (17,357)=67.72,\ p<.05$) as did the analyses of log cumulative response times during lever-presses 1-6 ($F\ (17,357)=56.02,\ p<.05$) and log cumulative response times during lever-presses 6-10 ($F\ (17,357)=54.92,\ p<.05$). Unfortunately, the significant Intertrial Interval effect observed in Experiment IV, failed to emerge in this study. However, as Figure 11 reveals, the data were in the same direction.

As in Experiment IV, it was possible to compare performance during the two portions of the FR10 ratio. Since the two portions involved different numbers of lever presses and hence different numbers of interresponse intervals, it was necessary to calculate mean IRTs for each portion. This measure was also analyzed by means of analysis of variance (Winer, 1962). The Intertrial Interval factor was a between-Ss factor with three levels (60, 15 or 0 seconds) while the Ratio Portion factor was a within-Ss factor with two levels (lever-presses 1-6 or lever-presses 6-10). Since no significant Intertrial Interval factor emerged from the analyses of log cumulative response times, it is not surprising that the analysis of mean IRTs also failed to yield a significant Intertrial Interval effect. The analysis did, however yield a significant Ratio Portion effect (F (1,21)=5.61, $p<.05$), resulting from the fact that IRTs were shorter during lever-presses 6-10 than lever-presses 1-6. Finally, the Ratio Portion x Intertrial Interval interaction was not significant.

A test for homogeneity of variance (Hays, 1962) revealed that log cumulative response times during lever-presses 1-10 were homogeneous (F_{Max} (7,3)=1.3, $p>.05$) as were log cumulative response times during lever-presses 1-6 (F_{Max} (7,3)=1.4, $p>.05$) and log cumulative response times during lever-presses 6-10 (F_{Max} (7,3)=1.7, $p>.05$). Furthermore, a similar test (Winer, 1962)

Figure 11. Mean log cumulative response time during lever-presses 1-10 as a function of intertrial interval duration and days in Experiment V.

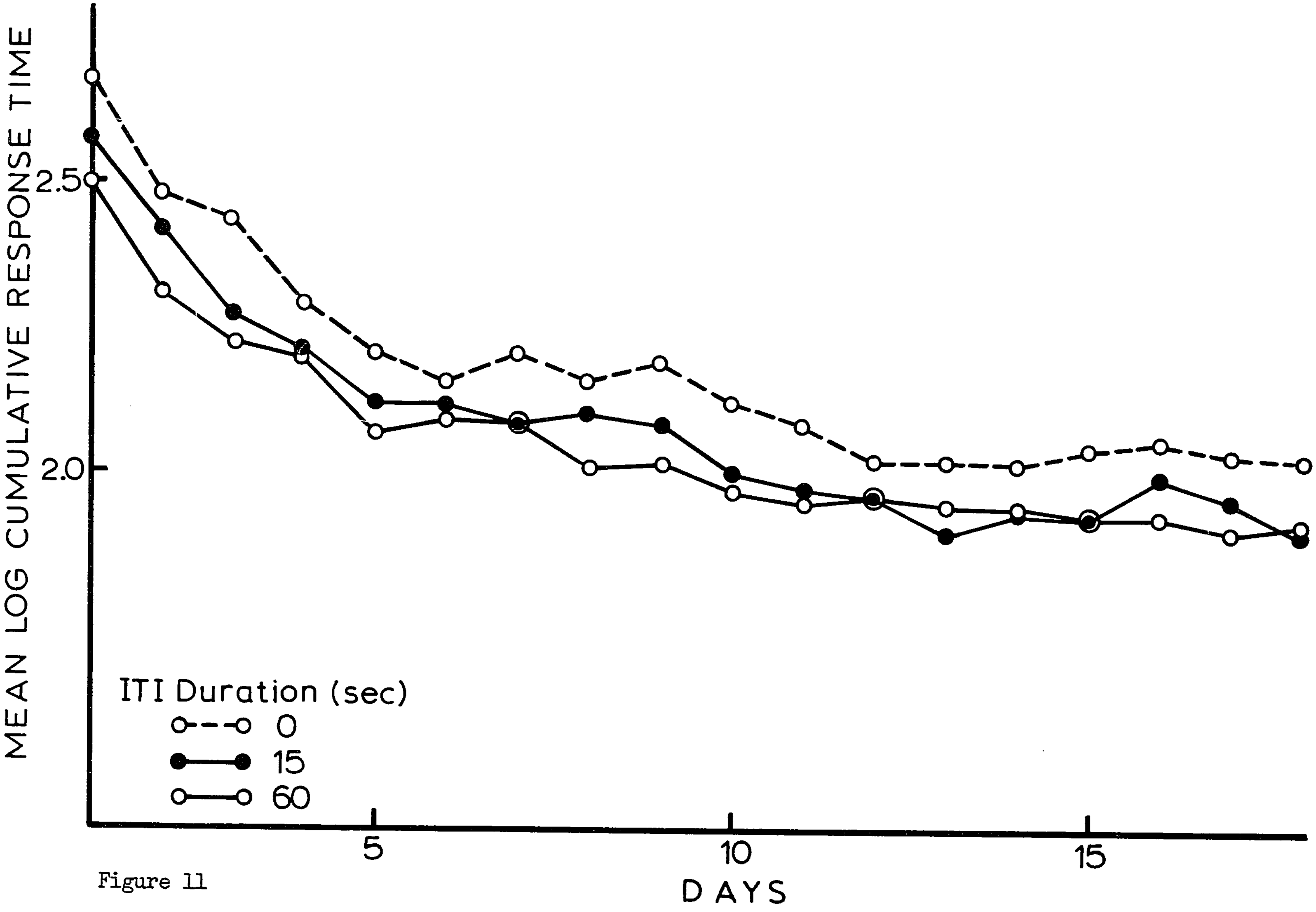
MEAN LOG CUMULATIVE RESPONSE TIME
2.5
2.0
DAYS
5
10
15
ITI Duration (sec)
0
15
60

Figure 11

revealed that the distribution of mean IRTs did not violate the assumption of homogeneity of variance (F_{Max} (7,6)=4.0, $p > .05$).

Complete summary tables for all the analyses of variance employed in Experiment V appear in Tables 14 to 17 of the Appendix.

Discussion

It is unfortunate that the significant Intertrial Interval factor observed in Experiment IV failed to emerge in the present study. It is satisfying to note, however, that the results in the present experiment are in the same direction with the 15-second ITI leading to shorter log cumulative response times than the 0-second ITI. There is no indication, however, that log cumulative response time is a curvilinear function of ITI. While Platt and Spence (1967) found a 30-second ITI to lead to longer latencies than a 10-second ITI, in the present experiment there was no difference between log cumulative response times when ITI was 60 or 15 seconds. In fact, while the difference was not significant, the 60-second ITI appears to have led to slightly shorter response times than the 15-second ITI. This suggests that had more Ss been used, thus increasing the power of the F test, log cumulative response time might have been a decreasing function of ITI duration. Further support for this conclusion is provided by the data obtained by Taus and Hearst (1970). These findings suggest that Platt and Spence (1967) may have been correct when they assumed that the effect of a long ITI (30 seconds) was to displace the organism away from the lever, thus increasing latencies.

Certainly, the present findings provide no support for the hypothesis that a relatively long response-produced ITI (60 seconds) punishes the response which produces it, resulting in longer response times.

Further evidence that the TO-punishment hypothesis is incorrect was provided by the IRT data. As indicated in the discussion of Experiment IV, longer IRTs would be expected during the latter portion of each ratio if the ITI was punishing the FR10 response. The results of both Experiment IV and the present experiment demonstrate the reverse to be the case.

Thus in the present research, no support is provided for the hypothesis that a response-produced ITI punishes the behavior which produces it. This suggests that the effect of partial reinforcement on the performance of a discrete-trial lever-pressing response depends on factors other than duration of the intertrial interval. As suggested earlier, these factors may include amount of acquisition training and amount of exteroceptive stimulation present during reinforcement.

GENERAL DISCUSSION

Many studies of the PRAE in the runway have demonstrated that during early acquisition (Trials 1-30), partial reinforcement leads to inferior performance relative to that produced by continuous reinforcement, but at asymptote, partial reinforcement leads to superior performance when compared to that generated by continuous reinforcement. In Experiment I, however, it was demonstrated that even after 360 trials in a discrete-trial lever-pressing situation, partial reinforcement led to inferior performance relative to that produced by continuous reinforcement. The results of Experiment II, on the other hand, showed that when 600 trials under conditions of continuous reinforcement preceded a switch to 50% reinforcement, there was a crossover, and at asymptote 50% reinforcement appeared to lead to faster response times than 100% reinforcement of FR10 responses, although this difference was not significant. This suggests that if enough training is given, it may be possible to produce a PRAE in the discrete-trial lever-pressing situation. As a result it was concluded that the discrete-trial lever-pressing situation and the runway situation may not be qualitatively different, at least with respect to the PRAE. The differences which did emerge might be attributed to the lack of response-preparedness (Seligman, 1970) of the lever-pressing response as well as to the organism's inability to practice this operant response, thus eliminating competing responses, prior to the experiment.

The results of Experiment IV indicated that the addition of a loud buzzer during each 5-second reinforcement or nonreinforcement period eliminated the large performance decrement produced by partial reinforcement throughout training in Experiment I. These data suggest yet another theoretical possibility. In the runway, the effect of percentage reinforcement on running speed differs depending on the portion of the runway in which performance is measured. The PRAE is never observed when running speed is measured in the vicinity of the goal box (Goodrich, 1958; Wagner, 1962). This has been attributed to the elicitation of a very strong r_F response since the stimuli in this region of the runway are very similar to goalbox stimuli. A strong r_F-s_F mechanism is in turn assumed to yield so many competing responses that all of them do not disappear during training but remain to interfere with partially reinforced running. It was indicated in the Discussion of Experiment IV that the stimuli present at the start of each FR10 chain are very similar to those present at the end of the chain. It follows that in the discrete-trial lever-pressing situation, the stimuli present at the start of each response chain are more like the stimuli present during reinforcement or nonreinforcement than is the case in the runway. As a result, the elicitation of a strong r_F response, and consequently many competing responses, might be expected not just at the end of, but throughout the entire FR10 chain. That is, measuring performance in a discrete-trial lever-pressing situation may be analagous to measuring performance in the goalbox region of the runway. It might be that the function of the buzzer in Experiment IV was to make the stimuli present during the FR10 chain less similar to those present during reinforcement or nonreinforcement and thus reduce the magnitude of the r_F response elicited by these chain stimuli.

At least two predictions can be made, based on this conclusion. First, extending the length of the lever-pressing chain to FR50 or FR100 should increase the number of interoceptive muscle-produced stimuli and, assuming such stimuli act in a cumulative fashion, this should make the stimulus complex available at the start of the chain less similar to that present at the end of the chain. A second way to accomplish this might be to add exteroceptive stimuli in a cumulative fashion throughout the FR chain (e.g., illumination of a cue light after the third lever press, onset of a tone after the seventh lever press and onset of a buzzer after the ninth lever press, with all three stimuli present during reinforcement or nonreinforcement). Either of these procedures should result in a PRAE, at least in the first part of the lever-pressing chain, after relatively few trials. A more complete description of a similar technique may be found elsewhere (Cole and Van Fleet, 1970). Secondly, the results of Experiment II suggest that extended training in the runway might result in the emergence of a PRAE in the goalbox region of the runway.

The failure of Experiments IV and V to confirm any of the predictions based on a conception of the ITI as a punisher suggests that the discrete-trial and free-operant situations may not be fundamentally different with respect to the effect of partial reinforcement on behavior. As outlined in the General Introduction, of the free-operant studies showing partial reinforcement to lead to superior performance, only three adequately controlled for the confounding effect of consummatory time. Skinner (1938) found local FR response rate to be a function of ratio size. This occurred only after extended training, however, in which rats made 387,000 lever presses on these three schedules. This suggests that in the free-operant lever-pressing situation as well as in the discrete-trial lever-pressing situation, partial reinforcement can be expected to lead to performance superior to that produced by continuous reinforcement only after extended training, unless the special procedures just discussed are employed. In another study, Jenkins, McFann and Clayton (1950) found corrected VI1 response rate to be higher than that on CRF after only 200 responses on CRF and 1010 responses on VI1. In this study, however, pigeons rather than rats served as experimental S̲s. In Seligman's terms, the key-peck response in the pigeon like the running response in the rat is prepared to be associated with the acquisition of food and hence less likely to provide a large number of competing responses. Similarily, Zeiler (1972) also using pigeons, found 90%, 70% or 50% reinforcement of FI responding to lead to higher local FI response rates than 100% reinforcement of FI responding after extended training (2,760 FIs under CRF and 1,980 FIs under the various partial schedules).

Thus, based on the limited evidence available, it can be hypothesized that in the free-operant situation as in the discrete-trial situation, partial reinforcement can be expected to lead to performance superior to that generated by continuous reinforcement after minimal training when a prepared response is employed but only after extended training when an unprepared response is employed. In those free-operant studies showing partial reinforcement of the unprepared lever-press response to lead to superior performance after minimal training, care has not been taken to control for the effects of consummatory time. Of those discrete-trial studies employing a lever-pressing response which demonstrated a PRAE after minimal training, or at least revealed no effect due to percentage reinforcement, only four (Gonzales, Bainbridge and Bitterman, 1966; Porter and Hug, 1965a, 1965b; Tombaugh, 1970) measured response speed in addition to latency. In these experiments, rats of the CF-Nelson strain, Long-Evans strain or Sprague-Dawley strain were employed and while Experiment IV in the present research revealed no differences between albino rats of the Wistar strain and hooded rats of the Long-Evans strain, the possibility of strain differences remains.

A final word should be said concerning the failure in Experiments IV and V to confirm the hypothesis that the ITI is a TO which punishes the behavior producing it. In Experiment III, the lever was present during the EXT component of the MULT (FR10-EXT) schedule whereas in Experiments IV and V, the lever was withdrawn during TO. Perhaps a response-produced period of extinction during which the organism responds in the presence of nonreinforcement is a more effective punisher than a period of TO during which the organism does not respond on the manipulandum. Support for this hypothesis is provided by Porter and Kopp (1967) who demonstrated slower response times in a situation in which each FR12 led to a 30-second ITI during which the lever was present, than one in which the lever was withdrawn during each ITI. This suggests that the presence or absence of the lever during nonreinforcement may be an important variable to consider in future research of this kind.

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APPENDIX

TABLE 1

SEQUENCE OF REINFORCED (R) AND NONREINFORCED (N) TRIALS DURING EACH DAILY SESSION FOR GROUP 50 IN EXPERIMENT I

Warm-up	Recorded Trials
RN	RNNR NRRN NRRN RNNR NRRN NR

TABLE 2

SUMMARY TABLE FOR PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE LATENCIES USED IN EXPERIMENT I

Source	df	MS	F
Percent Reinforcement	1,13	8.1793848	17.648496 *
S (error) **	13	.46346075	
Days	14,182	.045995681	1.617673
Percent Reinforcement x Days	14,182	.03731705	1.312445
Days x S (error)	182	.02843323	

* ($p<.05$)

** ("S" refers to subjects-within-groups in all summary tables)

TABLE 3

SUMMARY TABLE FOR PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES USED IN EXPERIMENT I

Source	df	MS	F
Percent Reinforcement	1,13	1.9848576	17.456033 *
S (error)	13	.11370611	
Days	14,182	.052335285	9.635402 *
Percent Reinforcement x Days	14,182	.007718631	1.421070
Days x S (error)	182	.005431562	

* ($\underline{p} < .05$)

TABLE 4

SEQUENCE OF REINFORCED (R) AND NONREINFORCED (N) TRIALS DURING EACH DAILY SESSION FOR GROUPS 70, 50 and 30 IN EXPERIMENT II

Percent Reinforcement	Trials
70	RRNR RRNN RRRR NRRR NNRR
50	RNNR NRRN NRRN NRNR RNNR
30	RNNR NNNR NNRN NRNN NRNN

TABLE 5

SUMMARY TABLE FOR PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE LATENCIES USED IN EXPERIMENT II

Source	df	MS	F
Percent Reinforcement	2,12	2.9572468	11.406264 *
S (error)	12	.25926516	
Days	29,348	.020702820	1.2676726
Percent Reinforcement x Days	58,348	.01458841	.8932760
Days x S (error)	348	.016331362	

* ($p<.05$)

TABLE 6

SUMMARY TABLE FOR PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES USED IN EXPERIMENT II

Source	df	MS	F
Percent Reinforcement	3,16	3.2570998	3.5927044 *
S (error)	16	.90658719	
Days	29,464	.047375971	2.336803 *
Percent Reinforcement x Days	87,464	.087311415	4.306605 *
Days x S (error)	464	.02027384	

* ($p < .05$)

TABLE 7

SUMMARY TABLE FOR PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES FOR GROUPS 100 AND 50 USED IN EXPERIMENT II

Source	df	MS	F
Percent Reinforcement	1,8	.033327470	.04808837
S (error)	8	.69275151	
Days	29,232	.025396020	3.360470 *
Percent Reinforcement x Days	29,232	.014371112	1.901624 *
Days x S (error)	232	.007557281	

* ($p < .05$)

TABLE 8

SEQUENCE OF REINFORCED (R) AND NONREINFORCED (N) TRIALS DURING EACH DAILY SESSION FOR GROUPS RECEIVING 50% REINFORCEMENT IN EXPERIMENT IV

RNNR NRRN NRRN NRNR RNNR

TABLE 9

CONDITIONS UNDER WHICH THE VARIOUS GROUPS WERE TRAINED IN EXPERIMENT IV

Strain	Percent Reinforcement	ITI Duration (sec)	Nomenclature
Albino	100	15	A - 100 - 15
Albino	100	0	A - 100 - 0
Albino	50	15	A - 50 - 15
Albino	50	0	A - 50 - 0
Hooded	100	15	H - 100 - 15
Hooded	100	0	H - 100 - 0
Hooded	50	15	H - 50 - 15
Hooded	50	0	H - 50 - 0

TABLE 10

SUMMARY TABLE FOR STRAIN X ITI X PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 1-10 USED IN EXPERIMENT IV

Source	df	MS	F	
Strain	1,40	.091932046	.51111808	
ITI	1,40	5.3733631	29.874491	*
Percent Reinforcement	1,40	.42800107	2.3795738	
Strain x ITI	1,40	.173693	.965688	
Strain x Percent Reinforcement	1,40	.45249721	2.5157658	
ITI x Percent Reinforcement	1,40	.4340612	2.413266	
Strain x ITI x Percent Reinforcement	1,40	.0375801	.208935	
S (error)	40	.179865		
Days	19,760	1.5855854	129.5963	*
Strain x Days	19,760	.0121277	.991249	
ITI x Days	19,760	.0156923	1.28259	
Percent Reinforcement x Days	19,760	.0169107	1.38218	
Strain x ITI x Days	19,760	.00606577	.495780	
Strain x Percent Reinforcement x Days	19,760	.00569704	.465642	
ITI x Percent Reinforcement x Days	19,760	.00737253	.602587	
Strain x ITI x Percent Reinforcement x Days	19,760	.0120174	.982228	
Days x S (error)	760	.01223480		

* ($p<.05$)

TABLE 11

SUMMARY TABLE FOR STRAIN X ITI X PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 1-6 USED IN EXPERIMENT IV

Source	df	MS	F
Strain	1,40	.051314750	.26733653
ITI	1,40	6.0892268	31.723291 *
Percent Reinforcement	1,40	.36613674	1.9074774
Strain x ITI	1,40	.135795	.707460
Strain x Percent Reinforcement	1,40	.37933029	1.9762124
ITI x Percent Reinforcement	1,40	.4020676	2.094668
Strain x ITI x Percent Reinforcement	1,40	.0371295	.193435
S (error)	40	.19194814	
Days	19,760	1.5289900	97.52443 *
Strain x Days	19,760	.0136647	.871587
ITI x Days	19,760	.0249355	1.59047
Percent Reinforcement x Days	19,760	.0189335	1.20765
Strain x ITI x Days	19,760	.00911517	.581398
Strain x Percent Reinforcement x Days	19,760	.00664286	.423705
ITI x Percent Reinforcement x Days	19,760	.00832154	.530777
Strain x ITI x Percent Reinforcement x Days	19,760	.0114177	.728264
Days x S (error)	760	.01567802	

* ($p < .05$)

TABLE 12

SUMMARY TABLE FOR STRAIN X ITI X PERCENT REINFORCEMENT X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 6-10 USED IN EXPERIMENT IV

Source	df	MS	F
Strain	1,40	.17095480	.83341119
ITI	1,40	4.0675784	19.829601 *
Percent Reinforcement	1,40	.51736951	2.5221962
Strain x ITI	1,40	.2514695	1.225923
Strain x Percent Reinforcement	1,40	.61974991	3.0213046
ITI x Percent Reinforcement	1,40	.51365238	2.504075
Strain x ITI x Percent Reinforcement	1,40	.0401142	.195558
S (error)	40	.20512659	
Days	19,760	1.6039036	116.6337 *
Strain x Days	19,760	.0143048	1.04022
ITI x Days	19,760	.0168385	1.22447
Percent Reinforcement x Days	19,760	.0187754	1.36532
Strain x ITI x Days	19,760	.00903022	.656665
Strain x Percent Reinforcement x Days	19,760	.00733192	.533168
ITI x Percent Reinforcement x Days	19,760	.0110643	.804579
Strain x ITI x Percent Reinforcement x Days	19,760	.0162727	1.18333
Days x S (error)	760	.01375163	

* ($p<.05$)

TABLE 13

SUMMARY TABLE FOR STRAIN X ITI X PERCENT REINFORCEMENT X RATIO PORTION ANALYSIS OF VARIANCE OF MEAN IRTs USED IN EXPERIMENT IV

Source	df	MS	F
Strain	1,40	.000152510	.002395099
ITI	1,40	1.19195898	30.146190 *
Percent Reinforcement	1,40	.21555626	3.3852023
Strain x ITI	1,40	.09468984	1.487056
Strain x Percent Reinforcement	1,40	.08814876	1.384332
ITI x Percent Reinforcement	1,40	.1076690	1.690888
Strain x ITI x Percent Reinforcement	1,40	.00786626	.123535
S (error)	40	.063676035	
Ratio Portion	1,40	.20766901	20.76318 *
Strain x Ratio Portion	1,40	.0023126	.023122
ITI x Ratio Portion	1,40	.0480168	4.80081 *
Percent Reinforcement x Ratio Portion	1,40	.00675026	.674905
Strain x ITI x Ratio Portion	1,40	.0036138	.36131
Strain x Percent Reinforcement x Ratio Portion	1,40	.00049959	.049950
ITI x Percent Reinforcement	1,40	.0003800	.03799
Strain x ITI x Percent Reinforcement x Ratio Portion	1,40	.0047460	.47452
Ratio Portion x S (error)	40	.01000179	

* ($p < .05$)

TABLE 14

SUMMARY TABLE FOR ITI X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 1-10 USED IN EXPERIMENT V

Source	df	MS	F
ITI	2,21	.40124707	1.7510471
S (error)	21	.22914694	
Days	17,357	.48732327	67.72344 *
ITI x Days	17,357	.00435118	.604685
Days x S (error)	357	.007195784	

* ($p<.05$)

TABLE 15

SUMMARY TABLE FOR ITI X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 1-6 USED IN EXPERIMENT V

Source	df	MS	F
ITI	2,21	.29474013	1.2015782
S (error)	21	.24529417	
Days	17,357	.45932813	56.02273 *
ITI x Days	34,357	.00544284	.663846
Days x S (error)	357	.008198961	

* ($p < .05$)

TABLE 16

SUMMARY TABLE FOR ITI X DAYS ANALYSIS OF VARIANCE OF LOG CUMULATIVE RESPONSE TIMES DURING LEVER PRESSES 6-10 USED IN EXPERIMENT V

Source	df	MS	F
ITI	2,21	.52819803	2.0810533
S (error)	21	.25381283	
Days	17,357	.52892545	54.92353 *
ITI x Days	17,357	.00598896	.621893
Days x S (error)	357	.9630217	.621893

* ($p < .05$)

TABLE 17

SUMMARY TABLE FOR ITI X RATIO PORTION ANALYSIS OF VARIANCE OF MEAN IRTs USED IN EXPERIMENT V

Source	df	MS	F
ITI	2,21	.12996944	1.8393846
S (error)	21	.070659196	
Ratio Portion	1,21	.025668750	5.609510 *
ITI x Ratio Portion	2,21	.00142431	.311262
Ratio Portion x S (error)	21	.004575935	

* ($p < .05$)