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APPROACH TO AND FORAGING FOR BURIED FOOD: VARIATIONS IN RESPONSE PERSISTENCE

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VARIATIONS IN RESPONSE PERSISTENCE

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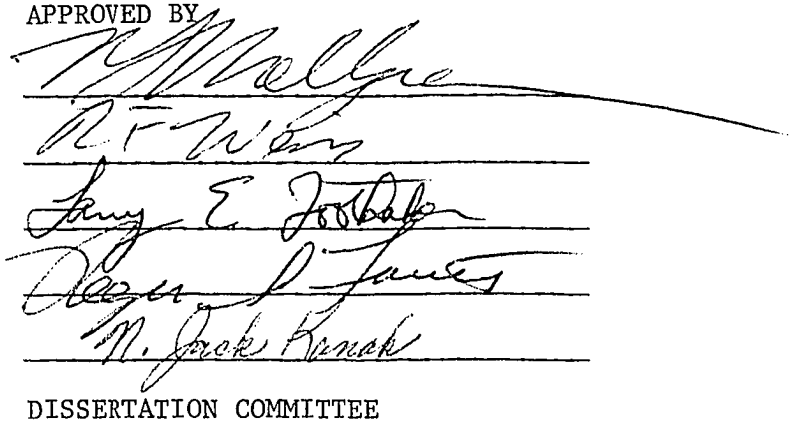

DISSERTATION COMMITTEE

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Abstract

The effects of reinforcement variables were examined when a traditional alleyway running response brought a rat to an enlarged goal box where food was buried beneath sand. In the first experiment, the independent variable was simply the consistent presences versus the intermittent presence of food in the sand (continuous vs. partial reinforcement) in acquisition and the effects of such schedules on the relative resistance to extinction of each response were measured. The effects of schedule of reinforcement were found to vary as a function of the nature of the response, namely, a traditional and surprisingly large partial reinforcement extinction effect was obtained in the approach response but a reversed partial reinforcement extinction effect was obtained in the digging response (i.e., rats that had, in acquisition always found food buried in the sand exhibited a greater amount of digging in extinction than did rats that had found food in the sand on only an intermittent basis.

A second experiment replicated the results of the first experiment and further demonstrated that the overall level of digging in extinction was dependent on the density of food (e.g., the number of food pellets on reinforced trials) but was independent of the intermittence of the presence of food. A number of possible theoretical accounts for these data are discussed. Further, it is proposed that this paradigm may be useful for the future examination of the various kinds of associations that an animal may acquire, e.g., S-S*, S-R, and R-S*.

Approach to and Foraging for Buried Food: Variations in Response Persistence

Learning experiments typically involve the establishment of a contingency or correlation between stimuli, responses, and reinforcers. Early learning theorists held that the particular stimulus, response or reinforcer, and even species of subject selected by the experimenter, was largely inconsequential; that irrespective of these particulars, laws of learning would be found that could be generalized to account for learned behavior under quite different sets of stimuli, responses, reinforcers, and contingencies. However, the nature of the associative process was dependent on one's theoretical perspective. Learning was represented as associations between stimuli and responses, S-R, (Guthrie, 1935; Hull, 1943), stimuli and reinforcers, S-S*, (Tolman, 1932), responses and reinforcers, R-S*, and stimuli and reinforcers, S-S*, (Konorski, 1948; 1967; Skinner, 1938), and stimuli and responses, S-R, and stimuli and reinforcers, S-S*, (Mowrer, 1960). A traditional empirical and theoretical effort has been the attempt to specify which of the above representations of association is correct.

A number of approaches, both experimental and theoretical, have been employed to determine the nature of association(s) in learning experiments (see Hearst (1975) for an extensive discussion). Hull, Guthrie and Tolman proposed that associations were of a single kind while Konorski,

Skinner, and Mowrer maintained that there were two kinds of association. The entire issue of the number and nature of associations however, eventually evolved to a belief that what was learned was largely dependent upon the procedure used to establish the association. The instrumental learning procedure produced an association, one element of which was the response, and a Pavlovian procedure produced an association between a stimulus and a reinforcer or unconditioned stimulus. To be sure, attempts were made to provide more substantive distinguishing criteria. One attempt supposed that responses subject to Pavlovian conditioning were restricted to autonomic, involuntary, or reflexive responses whild responses subject to instrumental contingencies were restricted to skeletal or voluntary responses. However the demonstration that responses controlled by the autonomic nervous system (e.g., heart rate, galvanic skin response) could be affected by explicit instrumental contingencies (see Miller (1969) for a review), and the ease with which Pavlovian conditioned responses could be interpreted as anticipatory of the unconditioned stimulus, hence potentially subject to implicit instrumental contingencies, brought this criterion into question. Thus it was generally conceded, largely by default, that the Pavlovian conditioning procedure produced an association between a stimulus and a reinforcer (S-S*) and the instrumental or operant learning procedure produced associations that contained, in some form, a response term (S-R or R-S*).

Two major assumptions have so far been identified: (1) that the laws of learning are general in that stimuli, responses and reinforcers are independent to the extent that the learning process itself does not vary with the particular stimulus, response, or reinforcer employed, and, (2)

that the nature of association is dependent solely on the contingencies that the experimenter arranged. Both of these assumptions have recently been subjected to serious challenge. An extensive literature on acquired taste aversions has shown that the long held view that temporal contiguity is necessary for the establishment of associations is questionable (Garcia, Ervin, & Koelling, 1966). It was once assumed that almost any two stimulus events were equally associable but it has since been shown that associations that are established may be highly selective, e.g., rats readily associate taste but not spatial location with illness (Garcia & Koelling, 1966; see Logue (1979) for a review). The exemplary data of Shettleworth (1973; 1975; 1978a) and Stevenson-Hinde (1975) have indicated that responses and reinforcers interact in complex ways: responses may be sensitive or insensitive to their consequences dependent on both the nature of the response and the nature of the consequence. Shettleworth (1973) found that food reinforcement of a rat's grooming behavior served to disrupt it, increasing it's probability but substantially changing it's topography. Stevenson-Hinde (1975) found that birds will learn to peck for food reinforcement but would not sing for food reinforcement. In Pavlovian conditioning paradigms, it has been shown that the obtained conditioned response depends not only on the nature of the unconditioned stimulus but also on the nature of the conditioned stimulus. Holland (1977) has observed substantially more rearing when a light CS was paired with food than when a tone CS was used. Shettleworth (1978b) has shown that the context within which stimuli are presented (large versus small apparatus) will affect the nature of the obtained conditioned response. These exemplary data have precipitated the conclusion on the part of many theorists (Bolles, 1970; Logue, 1979; Mackintosh, 1974; Rozin & Kalat, 1971;

Seligman, 1970), that at the very least, the assumption that there exist general laws of learning is in need of re-examination.

Brown and Jenkins' (1968) demonstration that a supposed pure operant, the pigeon's key peck, could be established and maintained despite the absence of a response-reinforcer contingency has seriously challenged the assumption that the nature of association depends on the contingencies established by the experimenter. Not only would the simple pairing of a lighted key result in key pecking, but the establishment of a negative response-reinforcer contingency would not eliminate the response (Peden, Brown, & Hearst, 1977; Williams & Williams, 1969). This is dramatic evidence that response-reinforcer contingencies are relatively ineffectual in controlling pigeon's key pecking behavior. Further damage to the view that the pigeon's key peck is instrumental (involves a response based associative process) was provided by Jenkins and Moore (1973) in demonstrating that the topography of the autoshaped key peck varied as a function of the nature of the reinforcer in a manner consistent with a Pavlovian interpretation, resembling a drinking CR or eating CR if the reinforcers were, respectively, water or grain. Such evidence provides strong support for the position that the response-reinforcer contingencies established by an experimenter may function only to ensure a close spatial and temporal relationship between stimuli and reinforcers and that all learning may thus be interpreted as the acquisition of S-S* associations (Bindra, 1974; 1976; 1978; Lajoie & Bindra, 1976; Moore, 1973).

The interpretation that all learning is S-S* in nature, has not been accepted without considerable reservation. It is generally recognized that under most circumstances, whether or not a response-reinforcer or

stimulus-reinforcer contingency is explicitly imposed in an experiment, both relationships are implicitly present (Hearst, 1975; Mackintosh & Dickinson, 1979), thus eliminating procedure alone as a criterion for distinguishing between the kind of associations that may be established in learning experiments. But as Mackintosh and Dickinson (1979) have pointed out, rather than reinterpreting all presumed instrumental behavior as being a result of the formulation of S-S* associations, it is perhaps more appropriate to develop a new theory of instrumental learning.

A substantial portion of recent literature has been devoted to an attempt to identify the conditions under which some form of response learning will take place and, the relative contribution of S-S* and R-S* associations in behavior modification. One such attempt (Jenkins, 1977) suggests that different response systems may be differentially sensitive to S-S* and R-S* contingencies. The prototypic experiment involved a comparison of head positioning and key pecking in pigeons. After the responses had been established with both R-S* and S-S* contingencies present, the elimination of the R-S* contingency resulted in a greater decrement in head positioning than in key pecking. Although neither response could be said to be controlled exclusively by R-S* or S-S* contingencies, apparently head positioning was controlled more by the R-S* contingency while key pecking was controlled more by the S-S* contingency. Shettleworth (1978b) also emphasizes response characteristics as potential distinguishing criteria between different associative processes. She hypothesized that responses which were easily modified by explicit R-S* contingencies may in fact have been found so because of an implicit S-S* contingency (Shettleworth, 1973; 1975). To the degree that this is the case, establishing only an explicit S-S* contingency

ought to result in s similar pattern of response modification as would occur if an explicit R-S* contingency were in fact in effect. Results of this procedure have, as yet, proved somewhat equivocal. For example, she has found food reinforced grooming to be suppressed by both positive R-S* and S-S* contingencies presumably because food has an unconditioned inhibitory effect on grooming behavior, an analysis that is entirely consistent with an S-S* interpretation of instrumental conditioning. Open rearing was subjected to the same Pavlovian analysis but was found to vary not only as a function of the nature of the S* (food or shock) but also with the training and testing context. For example, a CS+ for food in a small apparatus resulted in a large increase in open rearing but a decrease if the testing took place in an open field, a finding difficult to interpret in Pavlovian terms as presumably it is only the S* that determines the form of the CR (again, see Holland, 1977). Therefore an attempt to specify the role of S-S* associations in instrumental learning (presumed R-S* or S-R associations) by prior examination of the behavior under S-S* contingencies will not provide clear predictions as to the results of R-S* contingencies.

Another attempt to identify response characteristics differentially sensitive to R-S* and S-S* contingencies relied on quantitative characteristics of the same response. Schwartz and Williams' (1972) demonstration that key pecks in the presence of an omission contingency were charateristically short while those in the presence of a positive R-S* contingency were characteristically long was interpreted to mean that short duration pecks were reflexive (Pavlovian) while long duration pecks were operant in character (see also Schwartz, 1977 a & b).

A somewhat different approach than examining response characteristics

has been undertaken by Pearce and Hall (1978). It is well established in the Pavlovian conditioning literature that the better predictor of an S* will accrue the greater associative strength (Wagner, 1969). Pearce and Hall (1978) confirmed an analogous effect in an elegantly conceived operant lever pressing situation. If an exteroceptive stimulus was scheduled to be a better predictor of reinforcement than responding, then response rate dropped. If, on the other hand, responding proved to be the better predictor of reinforcement, response rate increased. Mackintosh and Dickinson (1979) have shown a similar effect when the response was wheel running. These data provide substantial support for the position that a response is most likely to enter into association if it is a better predictor of reinforcement than an exteroceptive stimulus, and vice versa. This result further suggests that the laws governing S-S* and R-S* associations are not qualitatively different, an important finding as it could be maintained that the two kinds of association are subject to different governing principles.

Finally Mellgren (cited in Morgan, 1979) and Mackintosh and Dickinson (1979) have noted that an S-S*, Pavlovian, analysis of appetitive instrumental learning restricts responding to simple approach. Mellgren reasoned that responses that did not in fact bring the subject closer to a goal box would, by definition, be "truly instrumental" responses. His paradigm required a rat to pass through a tunnel in order to enter a goal box containing food in a cup, however, direct passage was blocked by a ball so that entry into the goal box could only be accomplished by pulling the ball back into the start box. Thus, a simple approach response was not possible and more important, the rat was required to move away from the goal box and presumably very potent approach eliciting stimuli when removing the ball

from the tunnel. Despite this requirement, the ball-pull response was learned. If only approach responses were responsible for instrumental performance, the rat could conceiveably have entered the tunnel and remained there until the approach eliciting characteristics of stimuli in the apparatus extinguished, and never removed the ball from the tunnel.

Experiment 1

The experiments to be reported here are initial attempts to address a number of the issues discussed thus far. The procedure involves two topographically and perhaps functionally different responses. One response is running in an alleyway, and the other is digging in sand at the end of the alley where food pellets are buried. This paradigm is treated as an analogue to a natural environment in the following sense: an active-feeding animal must travel to a source of food and then, only upon arrival, engage in appropriate food-getting behavior (Charnov, Orians, & Hyatt, 1976). The traditional alleyway running response is an obvious analogue to traveling to a source of food (usually food pellets in a cup). Sand digging is a type of food-getting behavior. For example, Wong (1979) has interpreted his observation that increased amounts of sand digging accompanies food deprivation in rats, indicating that sand digging may be a species-specific food related behavior. The "schedule of reinforcement" present in the natural environment has a parallel in this procedure as well. When an animal forages for food in a restricted area or patch, continued consumption of food items usually depresses the rate at which subsequent food items will be found (Charnov, et. al., 1976). If each bit of sand moved by the subject is analogous to a bar press response in the traditional operant learning experiment, then digging is an adjusting variable ratio (VR) schedule with the ratio increasing as each food pellet is found.

This paradigm therefore provides the opportunity to examine the sensitivity of two different response classes to reinforcement variables (Jenkins, 1977). Further, by including what is presumed to be a response closely related to a rat's natural food-getting behavior, these experiments will allow generalizations to be made from laboratory behavior to natural behavior and vice versa which in turn may clarify the role of biological constraints in conventional animal learning paradigms. Related to this point is that insofar as the analogues that have been derived between traveling and foraging in the wild and running and digging in the laboratory are valid, an increase in the ecological validity of controlled laboratory research is provided. The benefit in generality to field and laboratory research is obvious.

The reinforcement variable manipulated in the first experiment is schedule of reinforcement. In operant terminology, the second-order schedule is CRF(Adj-VR) in one condition and VR-2(Adj VR) for the other. In straightforward language, in the first condition food is present in the sand on every trial, continuous reinforcement, and in the second it is present on half the trials and not on the other half, partial reinforcement. The possibility that digging in sand is biologically constrained suggests that schedule of reinforcement may affect it in ways different from its affect on a presumably non-constrained response like running. A substantial body of data and theory (e.g., Amsel, 1967; Capaldi, 1967) indicates that the running response should be more persistent after partial than after continuous reinforcement, a partial reinforcement extinction effect (PREE). Any straightforward associative account of the effects of schedule of reinforcement on digging behavior predicts a similar PREE. A major point

of interest is whether this same prediction for sand digging will hold true. Because of sanddigging's presumed close relationship to natural food-getting, it may vary in ways not consistent with the approach behavior.

Method

Subjects. Ten 100 day old naive male albino Holtzman rats served as subjects. They were housed in pairs until the start of the experiment whereupon each was individually housed under constant light conditions with water freely available. Each rat was subsequently handled and reduced to 80% free-feeding weight.

Apparatus. Two pieces of apparatus were used, one in the pretraining phase and another in the experiment proper. Pretraining took place in 4 small rooms (245 cm by 148 cm) under low levels of illumination. On the floor in the approximate center of the room, a plastic tub measuring 30 cm by 30 cm by 15 cm deep was placed. The tub contained sifted sand at a depth of 3.5 cm.

The experimental apparatus was a conventional wooden hardware cloth covered alleyway to which was attached an enlarged wooden clear Plexiglas covered goal box or patch (see note). The alleyway totaled 150 cm long, 10 cm wide and 10 cm high divided by a guillotine door into a 30 cm start box and a 120 cm run section. A guillotine door also separated the run section from the patch. The entire interior of the apparatus was painted flat black and the floor of the patch (30 x 37 x 18 cm high) was covered with 3.5 cm of sifted sand. Start, run and goal times were recorded by .01 second clocks; total trial duration was measured by a separate clock. Digging duration and number of digging bouts in the patch were measured by a .1 second clock and an electro-mechanical counter, both

of which were activated by a hand-held switch. The start clock and trial duration timer were activated by the opening of the start box door. Subsequently, the activation and termination of start, run, and goal clocks were controlled by photocells located, with respect to the start box door, at 6 cm, 105 cm, and 126 cm. The last photocell therefore, was situated 6 cm into the patch.

The experimentl phase was run in a semidarkened room with a continuous white masking noise present.

Throughout the pretraining and experimental phases, a reinforced trial consisted of 18 pellets (approximately 3 g) of Purina Pig Startina available, buried in the sand.

Procedure. Pretraining lasted for twelve days during which time rats were individually placed in the small rooms and allowed 20 minutes to find and eat the food pellets placed in the sand. On Day 1 of this phase, all 18 pellets were placed on top of the sand. Gradually, across the 12 days, the pellets were pshed deeper into the sand thus requiring that the rats dig for the food (see note 2). During this pretraining, one rat failed to demonstrate that it was digging (i.e., it ate no pellets) and was therefore discarded and replaced with another rat.

Subsequent to the pretraining, subjects were randomly assigned to 2 groups, continuous reinforcement (CR) or 50% partial reinforcement (PR).

During the experimental phase subjects were transported to the laboratory in squads of 2 rats, one rat from group CR and one from group PR. Across days of acquisition training and extinction, the order of which rat was run first in each pair was counterbalanced. Throughout acquisition, food reward was pushed to the bottom of the sand in the patch and the surface of the sand smoothed.

Acquisition training lasted for 10 days and consisted of 4 trials per day at an intertrial interval of 6 minutes for a total of 40 trials. Each trial lasted 5 minutes beginning with the opening of the start box door. A 60 second running criterion was maintained throughout acquisition and extinction: if a subject failed to complete any part of the running response (start, run, or goal) within this time period, it was gently pushed along or picked up and placed in the patch. On each trial, the experimenter recorded start, run, and goal times, the number of digging bouts, and the total duration of digging. The digging behavior was characterized by the rat pulling sand toward its body with its' forepaws and sniffing the sand. Vigorous pushing sand with the forepaws was infrequently observed but was accepted as a digging response as it would and did function to uncover food pellets that were subsequently eaten. Kicking sand with the hindpaws was very infrequently observed but was not accepted as a criterion digging response as, although it may serve to uncover food, substantial experience observing rats digging for food in other paradigms appeared to indicate that this was not a general food-getting strategy. Further, hindpaw digging, when observed, usually occurred concurrently with forepaw digging. A digging bout was considered terminated when the rat stopped digging as described above. Behaviors that were considered indicative that a digging bout had stopped were most often rearing or sniffing the walls of the patch.

After each trial the sand from the patch was removed and sifted through a screen, removing any remaining food pellets or other foreign substances. Within a day, each rat of a pair encountered different sand in the patch but between pairs the sand was mixed and redistributed, in an attempt to reduce the likelihood that odors in the sand could be used by the rat to predict the presence or absence of food.

Four different schedules of reinforcement were used (RNRN; NRNR; NRRN; RNNR) and were rotated across the 10 days of acquisition. After each rat had received its daily 4 trials, it was returned to its home cage and fed 1 hour later. In order to equate experience with the food reinforcer, each member of a squad was yoked with respect to number of food pellets obtained. Since the CR rats usually obtained more pellets than the PR rats, the PR rats were fed additional pellets in the home cage about 1 hour after trials so that both rats of a CR-PR squad received equal numbers of pellets within a day. In addition, both rats were fed enough Purina Rat Chow to maintain the 80% free-feeding weight.

The extinction phase lasted for 4 days, again 4 trials per day at an intertrial interval of 6 minutes. The same measures as were taken in acquisition were taken in extinction. The same control measures observed with respect to the sand in acquisition (e.g., sandmixing) were maintained in extinction but in addition, food pellets were frequently mixed into the sand and immediately sifted out. This was done in an attempt to maintain odors that resembled those of acquisition.

Results

A separate analysis of variance was conducted on the last day of acquisition and another across the 4 days of extinction for the five dependent variables: Start, Run, Goal speeds (1/Time) per trial, Number of Digging Bouts per trial, and proportion of Time Spent Digging per trial. The total bout duration of digging per trial was transformed to proportion of time spent digging to theat available to reflect the fact that opportunity to dig was dependent on the amount of time it took the subject to run to the patch and, in acquisition, the amount of time spent eating a pellet. The time it took to eat a pellet was estimated from a different experiment and was taken to be 8.32 seconds (SD = 4.16). This available time could vary from approximately 2 minutes to nearly 5 minutes.

Unless otherwise noted, all F-tests are significant at the levels reported using conventional degrees of freedom and when the degrees of freedom are corrected to account for the equal degree of dependence assumption in the groups by trials design (Geisser-Greenhous, 1958; see also Kirk, 1968). The failure to reject with the corrected degrees of freedom will be denoted by a "*". (See note 3.)

Terminal Acquisition. The results of Experiment 1 are shown in figures 1-4. Analysis of Start, Run, and Goal speeds revealed no statistically significant main effects or interactions. Similarly, no significant differences were detected in the number of digging bouts (see Table 1).

No difference was obtained in the proportion of time spent Digging (Schedule main effect, $F(1,8) < 1.0$). Group CR showed a general decrease in the proportion of time spent digging across trials while group PR showed a less systematic change as indicated by a Groups x Trials interaction ($F(3,24)=5.15$, $p < .007$*) with conventional degrees of freedom but this difference failed to reach an acceptable level of significance when the degrees of freedom were corrected. This could be interpreted as a change in state of deprivation between groups across trials since group CR consumed substantially more pellets than group PR (Schedule main effect $F(1,8)=43.81$, $p < .001$). Group CR averaged 8.38 g of food while group PR averaged only 4.4 g of food across the 4 trials.

In order to assess the possibility that the proportion of time spent digging differed on N versus R trials while minimizing the effects of extraneous variables (e.g., statiation, fatigue, dry mouths, etc.), it was determined that the first N and the first R trial would prove to be the best estimates of PR rats tendency to dig in sand. This comparison indicated that the proportion of time spent digging on N versus R trials did not differ ($t(24)=1.78$, $p > .05$; the means were .42 and .59 for N and R trials, respectively).

Insert Table 1 About Here

Extinction. In extinction a substantial partial reinforcement extinction effect (PREE) was obtained in Start speeds (Figure 1). Group PR was more persistent than group CR as reflected by a significant Schedule main effect ($F(1,8)=9.48$, $p < .02$), a Schedule x Trials interaction ($F(3,24)=$

19.99, $p < .001$), further substantiated by a Schedule x Days interaction ($F(3,24)=3.94$, $p < .02$*). Start speed was found to decrease as a function of Trials collapsed over days (Trials main effect, $F(3,24)=3.55$, $p < .03$*), but not as a function of Days (Days main effect $F(3,24) < 1.0$).

Insert Figures 1, 2, & 3

About Here

Group PR was also more persistent than group CR in the run measure (Figure 2). This is reflected as a significant Schedule main effect ($F(1,8)=40.28$, $p < .001$), a significant Schedule x Trials interaction ($F(3,24)=16.00$, $p < .001$), and a Schedule x Days interaction ($F(3,24)=5.98$, $p < .005$). Running speeds did reflect extinction both collapsed across days (Trials main effect $F(3,24)=16.13$, $p < .001$) and across trials (Days main effect $F(3,24)=7.27$, $p < .002$).

A somewhat different pattern of results was obtained in the goal speeds (Figure 3). Overall, group PR was more persistent than CR as revealed by a Schedule main effect ($F(1,8)=7.13$, $p < .03$) and group PR was more persistent than CR with respect to trials (Schedule x Trials interaction ($F(3,24)=4.29$, $p < .02$*). No other main effects or interactions approached an acceptable level of statistical significance.

The analysis of the number of Digging Bouts in extinction revealed that they decreased only as a function of trials and days (Trials main effect $F(3,24)=11.12$, $p < .001$ and Days main effect, $F(3,24)=6.04$, $p < .004$) and did not vary differentially between groups.

It is clear from Figure 4 that the proportion of time spent

digging by group CR is greater than that spent by group PR. Although the Schedule main effect was nonsignificant ($F(1,8)=2.21$, $p=.17$), group CR exhibited a greater proportion time digging with respect to trials (Schedule x Trials interaction $F(3,24)=5.57$, $p < .005$) and across days (Schedule x Days interaction $F(3,24)=9.91$, $p < .001$). The main effects of Trials and Days were also significant ($F(3,24)=14.83$, $p < .001$ and $F(3,24)=37.36$, $p < .001$).

Insert Figure 4 About Here

Discussion

As is evident from these data, a conventional and surprisingly large PREE was obtained in the running response despite the unconventional nature of the procedure. This result indicates that even though the schedule of reinforcement may not be directly analogous to the standard alleyway procedure, the running response remains sensitive to the schedule of reinforcement variable. Here, running was temporally and spatially separate from the food (i.e., the digging behavior intervened between running and obtaining food reinforcement).

The surprising result of this experiment from a strictly learning theoretical perspective is the reversed PREE exhibited in the digging behavior. As Wong (1979) noted, sand digging increases as a function of food deprivation and suggested the interpretation that sand digging may be a component of a rat's natural food-getting behavior. It is possible then to interpret the reversed PREE as simply a result of the digging behavior having a special biological relationship to food-getting. This biological interpretation, however, can not explain why <u>this</u> pattern, or for that matter, why any particular pattern should obtain. Further, it can not be said that digging was insensitive to reinforcement variables as it did vary as a function of schedule of reinforcement. It could still be maintained however, that this result is due to it's natural function and that for this reason it varies according to different behavioral principles, although principles as yet

unspecified. But it is at least premature to accept this biological interpretation on the basis of a single experiment as there are a number of other reinforcement variables and associative mechanisms that could potentially account for the differences in the digging behavior. It is the purpose of the next experiment to test this possibility.

Experiment II

A number of theoretical statements have been made about the function of reinforcement with regard to what it is that is reinforced. Shimp (e.g., 1975; 1978) has suggested that reinforcement operates to establish a structural or behavioral unit. Thus, rather than reinforcing a temporally contiguous, instantaneous response, the reinforcer serves to reinforce a piece or chunk of behavior that may span a substantial amount of time and/or behavior. Similarly, Logan (1956) has proposed that qualitatively similar responses that vary on some quantitative dimension may be considered different responses which may be separately reinforced, resulting in separate associations. According to such an analysis, qualitative and quantitative aspects of a response enter into association when followed by reinforcement and establish an association that is distinct from other qualitatively and quantitatively similar responses. An analysis of the sand digging behavior in Experiment 1 reveals that rate of reinforcement decreases as a function of the number of food pellets already obtained. Behaviorally, this means that increasingly long digging bout durations would be followed by reinforcement and theoretically, according to Shimp (1975; 1978) and Logan (1956), these varied bout durations may separately enter into association.

The following experiment is an attempt to test the possibility that quantitative aspects or behavioral units could be what is being learned in the patch. Specifically, the number of food pellets buried in the sand

were reduced. Reduction of the number of food pellets should increase the amount of digging the subject must do in order to obtain a food pellet. If these quantitative aspects of the response enter into association in acquisition, it is expected that this would be reflected in a substantial increase in the amount of digging observed in extinction as compared to a higher density of food (see note 4). In other words, if responses do enter into association with reinforcers (R-S*) and part of the response is it's duration, then this association should transfer to extinction, producing quantitatively more digging.

This experiment included two factorially combined independent variables, schedule and food density, such that four groups were obtained: partial reinforcement-high density (PR-H) and continuous reinforcement-high density (CR-H) which are identical to the groups of Experiment 1, and, partial reinforcement-low density (PR-L) and continuous reinforcement-low density (CR-L). There is as yet little basis upon which to predict whether or how schedule will interact with the density manipulation. But solely on the basis of the discussion thus far, it is predicted that schedule and density should not interact but that the density manipulation should have only an additive effect on the amount of digging in extinction.

Method

Subjects. A total of 24 naive male albino rats like those of Experiment 1 were used in this experiment (n=6/group).

Apparatus. The same apparatus as used in Experiment 1 was used here.

Procedure. The same general procedure of the pretraining and experimental phases used in Experiment 1 were observed here but with three modifications. First, the present experiment was conducted as 2 identical replications. Second, in Experiment 1, each subject was confined in either the experimental apparatus or a small holding cage totaling about 45-50 minutes. Although it would have been preferable to run squads that included 1 subject from each group, this would have necessitated a substantial change in intertrial interval and an excessive amount of time confined in the holding cage. Therefore, squads consisted of 1 PR-H and 1 CR-H or 1 PR-L and 1 CR-L. Third, in an attempt to equate experience with the food pellets across all groups, all subjects received 50 food pellets daily. Those pellets not obtained in the experimental apparatus were provided in the home cage.

The same 50% partial reinforcement schedules used in Experiment 1 were used here. High density reinforcement was defined as 18 pellets (as in Experiment 1, approximately 3 g) and low density reinforcement as 6 pellets (approximately 1 g) of Purina Pig Startina.

Results

A separate analysis of variance was conducted for the last day of acquisition and another across extinction for each dependent variable. Again, as in Experiment 1, Start, Run, and Goal times were converted to speeds for analysis, total number of Digging Bouts, and the proportion of time spent Digging were also analyzed.

Again, those F-tests that were significant with conventional degrees of freedom but failed to reach significance when corrected degrees of freedom were used are denoted by a "*". (See note 5.)

The results of Experiment 2 are shown in Figures 4-8.

Terminal Acquisition. The last day of acquisition was analyzed as a 2(Schedule) x 2(Density) x 2(Replications) x 4(Trials) ANOVA. A trend indicating that continuous reinforcement produced faster Start speeds than partial reinforcement under high food density but slower speeds under low density was indicated by a marginally significant Schedule x Density interaction ($F(1,16)= 3.04$, $p < .10$*). Analysis of speed in the run section of the alley revealed no significant differences. Goal speeds were found to be faster under continuous reinforcement than partial reinforcement (Schedule main effect $F(1,16)=5.47$, $p < .04$) and to vary unsystematically across trials (Trials main effect $F(3,48)=3.25$, $p < .03$*). No other effects in the running measures reached statistical significance.

Analysis of the number of Digging Bouts indicated that high food density resulted in more bouts than low density (Density main effect $F(1,16)=$

24.88, $p < .001$, see Table 1.) No other effects in terms of the number of bouts approached significance. Analysis of the proportion of time spent digging showed that high food density resulted in less proportion of time spent digging than did low density (Density main effect $F(1,16)=18.95$, $p < .001$). Across trials, low density of food resulted in increasing proportions of time digging while high density resulted in decreasing proportions of time digging (Density x Trials interaction ($F(3,48)=3.25$, $p < .01$*). Further, a significant Schedule x Trials interaction ($F(3,48)=10.11$, $p < .001$) was obtained. Subsequent individual comparisons indicated that this was largely due to significantly less digging by partially reinforced groups than continuously reinforced groups on trial 3, which was an N trial in PR groups, ($t(48)=2.90$, $p < .05$).

Extinction. Extinction was analyzed as a 2(Schedule) x 2(Density) x 2(Replications) x 4(Trials) x (Days) ANOVA.

Insert Figures 5, 6, 7

About Here

As in Experiment 1, a substantial PREE was obtained in Start speeds as shown in Figure 5 and as best indicated by a Schedule main effect ($F(1,16)=9.86$, $p < .007$), a Schedule x Trials interaction ($F(3,48)=3.56$, $p < .03$*), and a Schedule x Days interaction ($F(3,48)=4.55$, $p < .008$. Density did not appear to have a strong effect on Start speeds although a Density x Schedule x Trials interaction was obtained ($F(3,48)=3.28$, $p < .03$* and a marginally significant Density x Schedule x Days interaction was found ($F(3,48)=2.29$, $p < .09$*). The Replications factor interacted with Trials

($F(3,48)=3.16$, $p < .04$*); Days, Density and Schedule ($F(3,48)=2.29$, $p < .06$*); and Trials, Days, and Schedule ($F(9,144)=2.00$, $p < .05$*).

Running speeds in the run section of the alley may provide a better measure of persistence as, although a Replications main effect was obtained ($F(1,16)=4.53$, $p < .05$) it did not interact with any other factor. Partial reinforcement resulted in greater persistence as shown by a significant Schedule main effect ($F(1,16)=45.37$, $p < .001$), a Schedule x Trials ($F(3,48)=6.27$, $p < .002$) and a Schedule x Days interaction ($F(3,48)=6.19$, $p < .002$; see Figure 6). The effect of Density was found to be dependent upon the schedule of reinforcement, high density producing faster speeds than low density if the schedule was partial but slower speeds if the schedule was continuous (Schedule x Density interaction $F(1,16)=7.41$, $p < .02$). High density tended to produce faster speeds across days than did low density collapsed across schedule (Density x Days interaction $F(3,48)=6.19$, $p < .002$).

Analysis of Goal speeds (Figure 7) also revealed a substantial PREE (Schedule main effect $F(1,16)=12.44$, $p < .004$; Schedule x Trials interaction $F(3,48)=3.72$, $p < .02$*; Schedule x Days interaction $F(3,48)=9.83$, $p < .001$; and a Schedule x Days x Trials interaction $F(9,144)=3.02$, $p < .003$*). Low density produced faster speeds across days of extinction than did high density (Density x Days interaction $F(3,48)=4.01$, $p < .02$). Further, density and Schedule interacted with Trials and Days ($F(9,144)=2.49$, $p < .02$*) indicating that group CR-L was more persistent than group CR-H with respect to trials but not days and that PR groups were more persistent than CR groups with respect to both Days and Trials but irrespective of Density. Again in the goal measure, Replications was found to interact (Days x Replications x Density $F(3,48)=2.82$, $p < .05$*; Trials x Days x Replications $F(9,144)=2.33$, $p < .02$*)

For the analysis of number of Bouts, extinction did occur both within days (Trials main effect $F(3,48)=19.73$, $p < .001$) and across Days (Days main effect $F(3,48)=5.14$, $p < .001$). A Replications main effect was obtained ($F(1,16)=5.14$, $p < .04$) and interacted with Density ($F(1,16)=13.68$, $p < .003$). No other significant effects were obtained.

Insert Figure 8 About Here

A similar pattern of results was obtained in the proportion of time spent Digging as was found in Experiment 1, a reversed PREE (see Figure 8). CR groups were more persistent than PR groups (Schedule main effect $F(1,16)=4.06$, $p < .06$), and CR groups exhibited a greater proportion of time Digging than did PR groups across Days (Schedule x Days interaction $F(3,48)=5.61$, $p < .003$). It is evident however that rates of extinction were greater for CR than PR groups across trials within days (Schedule x Trials interaction $F(3,48)=9.86$, $p < .001$). It is evident that low food density produced more digging than did high density (Density main effect $F(1,16)=10.44$, $p < .006$) and the significant Schedule x Density x Days interaction indicated that group PR-H exhibited little decrease in proportion of time digging across days in comparison to groups PR-L, CR-H, and CR-L while the overall level of digging across days of extinction was dependent on food density ($F(3,48)=6.86$, $p < .001$). Significant Trials and Days main effects again revealed that the proportion of time spent digging was decreasing, that extinction was occurring ($F(3,48)=21.08$, $p < .001$, and $F(3,48)=121.72$, $p < .001$, respectively). Replications again interacted with some factors (Density x Replications x Trials $F(3,48)=3.77$, $p < .02$*; Schedule x Replications x Trials $F(3,48)=4.72$,

$p < .007$; and, Schedule x Replications x Days x Trials $F(9,144)=2.06$, $p < .04$*) but no meaningful interpretation of these interactions was evident.

Discussion

As is evident from these results, groups PR-H and CR-H exhibited a surprisingly similar behavioral pattern as was observed in Experiment 1, PR-H subjects were more persistent than CR-H in the running response but less persistent in the digging behavior.

The prediction that formed the basis of this experiment, that the food reward was serving to establish associations that included quantitative or structural aspects of the digging behavior, was confirmed. If these rats were associating their digging behavior with it's consequence, and one aspect of that response is it's duration, then digging in extinction should and did increase inversely with food density. Specifically, groups PR-L and CR-L showed an overall greater proportion of time spent digging than groups PR-H and CR-H.

An additional aspect of these data indicate that while the food density manipulation in the patch served to reinforce differing bout durations (i.e., an inverse relationship was obtained between food density and amount of digging in extinction), it also functioned as a magnitude manipulation with respect to the running response. This can be interpreted to indicate that in acquisition, these rats were somehow treating reinforcement obtained across time (and responding) in the patch as a unit.

General Discussion

The results of these experiments can be quite easily summarised. First with respect to the running response, a robust PREE was obtained. Further, the density or number of pellets available in the patch produced a pattern of results similar to those obtained in conventional alleyways where magnitude of reinforcement is manipulated by having all pellets together in a food cup and sufficient time is allowed for the rat to eat all of them. A large number of food pellets produced greater persistence in extinction than a small number when the schedule in acquisition was intermittent, but, if the schedule was continuous, a small number of pellets produced greater persistence than a large number. This replicates conventional alleyway results (e.g., Wagner, 1961). Second, with respect to the digging response, continuous reinforcement in acquisition produced a greater daily time spent digging in extinction than did intermittent reinforcement for both densities of pellets. In addition, an inverse relationship between density of food in acquisition and amount of digging observed in both acquisition and extinction was obtained.

Little difficulty is encountered in explaining the effect of schedule on the running response as the data do not appear to substantially differ from those obtained in conventional alleyway studies. There is no obvious reason then than an account of the running response in these alley-patch experiments should vary from those proposed for the conventional alley

procedure (e.g., Sequential Theory, Capaldi, 1967; Frustration Theory, Amsel, 1967). These experiments were not designed to test the different accounts of the PREE in the alley-patch context, but this does remain an empirical question and one that could easily be examined.

As noted earlier, it is premature to simply dismiss the observed pattern of digging as reflecting solely a biological constraint since digging did vary as a result of the manipulation of experiential variables: first schedule of reinforcement did affect digging despite the fact that the pattern itself was unanticipated and, second, the results of experiment II were in fact predicted from an associative framework. It is obvious then that associative processes of some sort are operating and that the pattern is not simply a function of the nature of the digging response. The possibility that the reversed PREE in digging duration is a result of some complex biological-experiential interaction can not be rejected out of hand, and remains subject to experimental analysis. The remainder of this discussion will however, be concerned with providing an associative framework within which the persistence of running and especially digging can understood.

Consider first the nature of nonreinforced (N) and reinforced (R) trials. When a PR rat enters the goal box, it is in a situation where there may or may not be food, and, in order to determine the presence or absence of food, the rat must dig, but the duration of digging an any particular trial is to some degree variable. This is a very different situation than occurs in the simple straight alley where the presence or absence of food in the food cup is an immediate and salient event. In the sand patch, N and R trials are not so immediately discriminable.

One of the possible things to learn for a PR rat during acquisition is to discriminate N trials form R trials. Assuming that PR rats have in fact learned such a discrimination in these patch experiments, it would be expected that in extinction PR rats should dig less than CR rats. CR rats having never before encountered an N trial cannot as easily discriminate the absence of food and hence would dig more. This discrimination hypothesis runs into several difficulties however.

First, the discrimination hypothesis suggest that less digging should occur on N trials than on R trials in PR groups during acquisition. But there is little evidence that this is the case (see table 1). Presumably a PR rat should show some behavioral evidence of such a discrimination but terminal acquisition digging times broken down with respect to N versus R trials indicate no such discrimination has been learned, there being approximately an equal amount of digging on both N and R trials. Note that there was a difference in digging duration between N and R trials for PR-L rats in Experiment II that is consistent with this discrimination hypothesis. Yet, the discrimination hypothesis would presumably predict that such a discrimination would be easier for PR-H rats because the discrepancy between N and R trials is greater for PR-H than for PR-L rats. An arguement could be made however, that the discrimination was incompletely learned and after 40 trials was poorly reflected in performance. This seems an unconvincing arguement but of course could be tested simply by increasing the number of acquisition trials to some number where such a difference was observed.

The discrimination hypothesis runs into further and perhaps more serious difficulties if the running and digging responses in extinction are considered concurrently. If the observed effects are due to CR rats

nondiscrimination of N and R trials, it would follow that the CR running response should be at least as persistent in extinction as the digging response. Clearly, PR rats are much more persistent runners than CR rats. Thus, it follows that CR rats were discriminating N trials more readily than PR rats. This the traditional "discrimination hypothesis" as applied to the PREE (Mowrer & Jones, 1945), but any straightforward application to the results of these experiments results in contradictory predictions. It is interesting to not that a number of instances occured where CR rats simply refused to enter the patch but when placed in the patch by the experimenter, subsequently exhibited a substantial amount of digging.

Another explanation will be referred to as the "rule learning hypothesis". Conceivably, the PR rats could be learning and using some sort of rule which is different than what the CR rats learn and use. At its simplest, it could take the form "dig in sand until a pellet is found, eat it, and continue, or dig until some criterion time has passed with no pellet found, then stop." The most simple and reasonable criterion being the approximate amount of time or digging necessary to find the first pellet on an R trial. Similarly CR rats could learn and use the simple rule, "if sand is encountered, dig for food." It follows rather directly from these rules that in extinction, the amount of time spent digging by PR rats would be restricted by the stop rule, whereas the time spent digging by CR rats would not. It follows that CR rats should dig more than PR rats, as observed.

One aspect of these data that has not yet been discussed is the number of digging bouts emitted. No substantial difference was obtained between the number of bouts on N versus R trials for PR rats

nor between PR and CR rats in acquisition. If it were the case that these rats were using these particular rules we would expect substantially fewer bouts (and less digging) on N as compared to R trials. (Specifically, these rules should produce a single digging bout on N trials in acquisition and extinction that would approximate or be only slightly greater than the average amount of time digging required to obtain the first pellet on R trials). The difficulty in maintaining this rule hypothesis is that once the rat stops digging, it has presumably reached that criterion and should then stop digging altogether. Contrary to this, the PR rat continues initiating and terminating digging bouts at the same level it would if there had been food buried in the sand. Thus the rule hypothesis, at least in this particular form, cannot adequately account for this data. It may be possible to formulate other more complex rules, attempting to formulate one that would be in accord with the data. It seems reasonable to suspect that if the behavior of these rats was guided by a rule, it would be a rule nearer the simple form mentioned here, rather than a more complex one.

Some theories of persistence (e.g., Amsel, 1967) have suggested that extinction after continuous reinforcement in acquisition results in the elicitation of primary frustration. As primary frustration has presumed motivating properties (Amsel and Roussel, 1952), the increased persistence of CR groups over PR groups in the digging behavior could be interpreted as reflecting frustration motivated digging. Again however, as was seen in the critique of the discrimination hypothesis, if the running and digging behaviors are examined concurrently, a frustration interpretation such as this would incorrectly predict that CR groups would be more

persistent in extinction than PR groups in the running response as well as the digging response. Since frustration serves to increase the vigor of digging, it would presumably serve a similar function for running. Unless some auxillary principle is proposed defining the circumstances under which frustration will increase or decrease instrumental responding in extinction this particular useage of frustration remains post hoc and arbitrary, accomplishing little more than attaching a familiar label to the result. This is not to say that primary frustration may not operate in this paradigm. An interpretation that remains consistent for both the running and digging responses is that frustration is reflected in the substantial decrement in digging across trials within days as is exhibited by CR groups. Presumably, primary frustration would accumulate for CR rats as a function of trials within a day inhibiting the previously reinforced digging response, but dissipate between days. PR rats however, having already experienced nonreward in acquisition would not experience this primary frustration in extinction and therefore would show minimal within-day decrements in digging. As a result, and as observed, rate of extinction should be greater for CR than for PR groups in the digging behavior within days. Thus, primary frustration may inhibit instrumental responding irrespective of the nature of the instrumental response. Frustration viewed in this manner is far more consistant with conventional usage, serving to inhibit a previously rewarded response rather than facilitating it.

There are several potentially important characteristics of this experimental paradigm that have not yet been discussed. As noted earlier, a substantial portion of current learning literature relies heavily on S - S^*

associations as the mechanism for the modification and maintenance of behavior. This S - S* interpretation of instrumental behavior implies that there are particular localizable stimuli in the environment toward which an animal responds. In the alleyway, a number of stimuli are available such that it is easy to construe the rat as approaching particular localized stimuli, stimuli which are temporally and spatially associated with the location of food. Researchers have demonstrated that the localizability of a stimulus is important in determining whether or not a stimulus will effectively guide behavior. For example, Wasserman (1973) demonstrated that acquisition of an autoshaped key peck was readily acquired in a brightly lit chamber but not in a darkened chamber. Illumination of the key light in the darkened chamber served to illuminate portions of the apparatus, thus providing other stimuli toward which the pigeons responded. In the brightly lit chamber, unlike the darkened chamber, the illumination of the key was highly localized and did not provide other redundant stimuli, and as a result, could and did effectively guide behavior.

The stimulus complex in the patch is quite different. In the patch, the relevant stimulus is sand but rather than being localized it is quite diffuse, much in the same manner as the light in Wasserman's darkened chamber. Therefore, if it is maintained that only an association between sand and food is established, conceivably the rat would be surrounded by equally potent response eliciting stimuli, none of which would be more effective than another.

In addition to being a diffuse stimulus, sand alone is also a relatively poor predictor of food. This is particularly the case for PR groups but in all groups, digging must occur before food can be obtained.

Therefore, consistent with Wagner's (1969) view, since digging is a better predictor of food, digging should be strongly associated with food. Mackintosh and Dickinson (1979) and Pearce and Hall (1979) have independently demonstrated that the extent to which behavior is predictive of food, as compared to exteroceptive stimuli, determines the degree to which the behavior is associated with food.

In summary, two factors lead to the conclusion that the digging response itself has entered into an R -S* association: First, sand is not localized in such a way that it may serve to guide behavior in the sense that it elicits approach responses, and second, the digging response is a better predictor of food than is sand. This alone, of course, does not account for the observed reversed PREE or the observation that time spent digging in extinction is inversely related to the number of pellets buried in the sand. However, it is critical to the following account of the reversed PREE that digging is in fact associated with food.

If as Shimp (1975; 1978) and Logan (1956) suggest, food reinforcement serves to condition both qualitative and quantitative aspects of behavior, and further, that in these patch experiments, as food is consumed, the ease with which subsequent food is found decreases, it follows that on reinforced trials, increasingly long digging bouts would be associated with food. Further, it appears reasonable to assume here that, on N trials in acquisition, longer digging bouts are emitted and are not followed by a pellet than are bouts followed by food on reinforced trials. (Informal observation appears to support this assumption, especially in early acquisition). As a result, as acquisition progresses, these long nonreinforced bouts would extinguish. Bout durations approximating the

longest reinforced bout on reinforced trials would continue to occur on nonreinforced trials, and so would functionally be on a partial reinforcement schedule. Behaviorally, this analysis, predicts that at the end of acquisition, the amount of digging exhibited should not differ between CR and PR groups, nor between N and R trials for PR groups as both have similar bout durations conditioned. Further, the overall amount of digging exhibited should be determined by the amount of digging required to obtain a food pellet (e.g., not by schedule but by food density). The rats experiencing the low density patch must dig longer for each pellet (on the average) than those experiencing the high density. Therefore, longer duration bouts will be maintained for the low density patches condition than the high density one. This analysis is in general consistent with the terminal acquisition data.

When subsequently placed in extinction, both CR and PR groups will emit conditioned digging bouts, but it is also assumed that some generalization of digging bout durations will occur. Specifically, digging should generalize to bout durations longer than those conditioned in acquisition but only for CR groups because throughout acquisition PR rats have had long digging bouts extinguished on N trials. It follows from this analysis that (1) total time spent digging will be greater for CR groups over that exhibited by PR groups (a reversed PREE), (2) that the absolute (or proportion) of time spent digging should vary inversely with food density, and (3) the number of bouts emitted by CR and PR groups should not differ.

It is obvious that this analysis relies on the proposition that responses enter into association with reinforcers, R - S^* associations.

Although it may be argued that proprioceptive stimuli arising from digging are what are actually being associated (Spence, 1960), this is not necessarily a flaw in the present account. The position maintained here is that some element of responding enters into association. Reducing responses to stimuli or defining responses as stimuli may however serve as a possible molecular account of how responses are associated with their consequences. Further, to eliminate the possibility that responses may be associated with reinforcers by definition alone, especially in the context of these data, appears unjustified.

In general the results of these experiments are consistent with the bout duration hypothesis discussed. This interpretation does however, rely on some reasonable, but yet untested assumptions: (1) That digging is not a special response due to a possible biological relation to food-getting (2) that sand is not a localized stimulus capable of effectively guiding behavior, and (3) that through acquisition and extinction the distribution of bout durations within a particular food density vary as described. It is obvious that further experimental work may be done to directly test these assumptions and to provide support for the bout duration hypothesis offered here.

Notes

1. Since much of the rationale for conducting these experiments relies on the distinct ecological character of the procedure, the term patch rather than goal box is preferred and maintained. Although the patch is analogous to the conventional goal box, it is sufficiently different as to deserve a special label.
2. The purpose of the pretraining phase was not to teach the rats how to dig but rather to allow the rats the opportunity to learn that food may be found buried in the sand. No position is taken with regard to what type of association, R-S* and S-S*, is established during this phase. It remains an interesting question however, what effect this pretraining may have on subsequent behavior in the experimental phase.
3. The .05 critical value used in experiment 1 for any F-test which included a Trials or Days factor was $F(1,8) = 5.32$. This is a conservative degrees of freedom modification that accounts for the violation of the equal degree of dependence assumption in the groups by trials design.
4. In conventional alleyway experiments, magnitude of reinforcement manipulations are often accomplished by variations in the number of pellets placed in the goal box food cup (although see Amsel, Hug, & Surridge, 1968). Since a variation in the number of food pellets in the sand results in a change in the number of pellets per unit area,

a more descriptive term is density. Magnitude in this paradigm is more appropriately reserved for manipulations that vary the actual size of an individual food pellet.

5. The .05 critical value used in experiment 2 for any F-test which included a Trials and/or Days factor was $F(1,16) = 4.49$.

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Terminal Acquisition

	Group	Mean Number of Pellets/R Trial	Mean Proportion of Time Spent Digging		Mean Number of Bouts Per Trial	Proportion of Time Spent Digging
			First N	First R		
Experiment 1	CR	12.45	-	.65	14.10	.58
	PR	13.20	.42	.59	13.45	.47
Experiment 2	CR-H	12.52	-	.61	13.88	.54
	CR-L	5.63	-	.76	10.38	.78
	PR-H	13.17	.43	.48	13.68	.43
	PR-L	5.33	.51	.84	8.75	.67

TABLE 1. Summary of terminal acquisition (Day 10) data for Experiment 1 and Experiment 2. See text for statistical analyses.

Figure Captions

Figure 1. Start speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 1.

Figure 2. Run speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 1.

Figure 3. Goal speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 1.

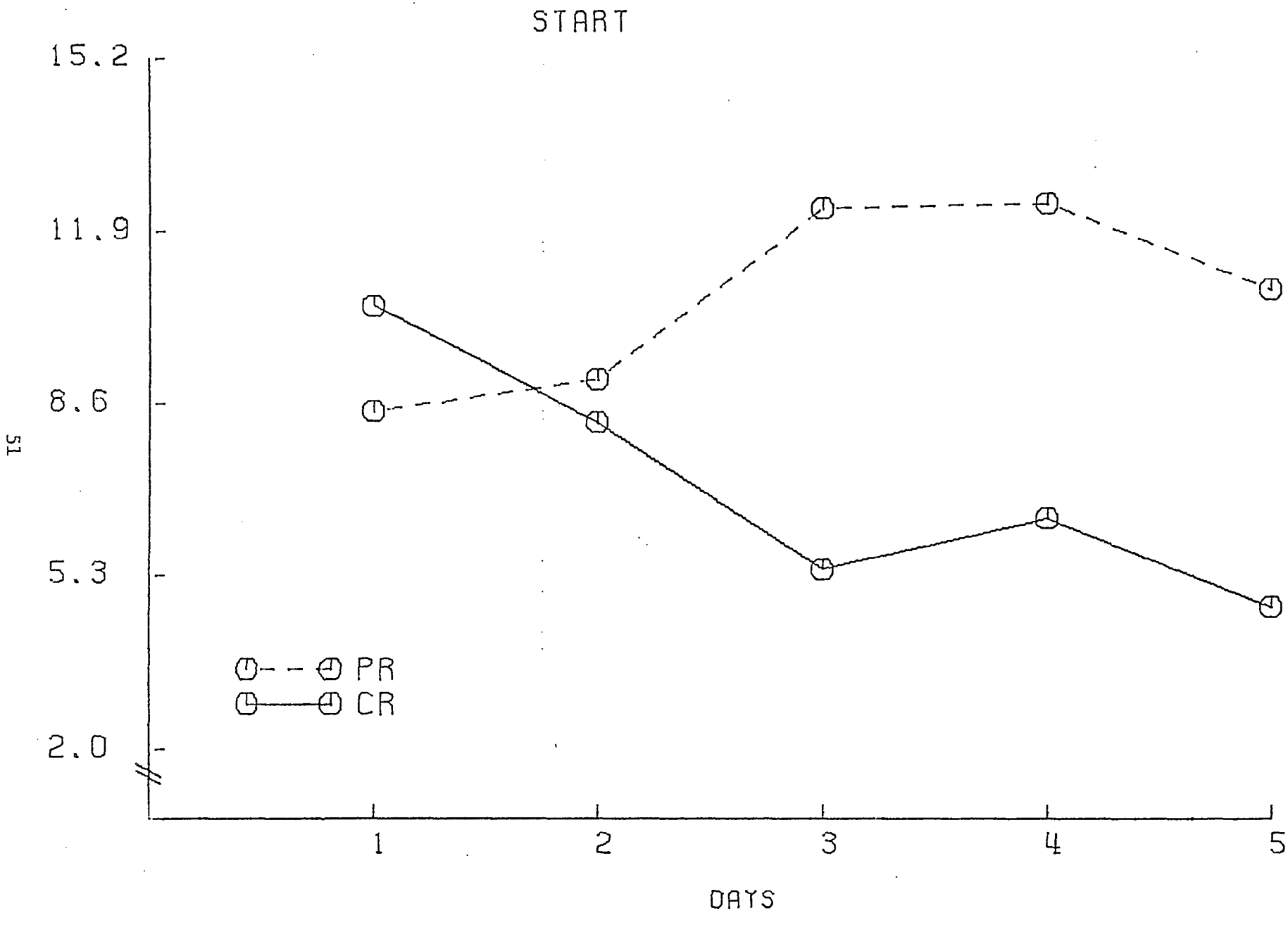
Figure 4. Proportion of time spent digging on each trial of the last day of acquisition (1-4) and the four days of extinction (5-20) in Experiment 1.

Figure 5. Start speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 2.

Figure 6. Run speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 2.

Figure 7. Goal Speeds on the last day of acquisition (1) and the four days of extinction (2-5) in Experiment 2.

Figure 8. Proportion of time spent digging on each trial of the last day of acquisition (1-4) and the four days of extinction (5-20) in Experiment 2.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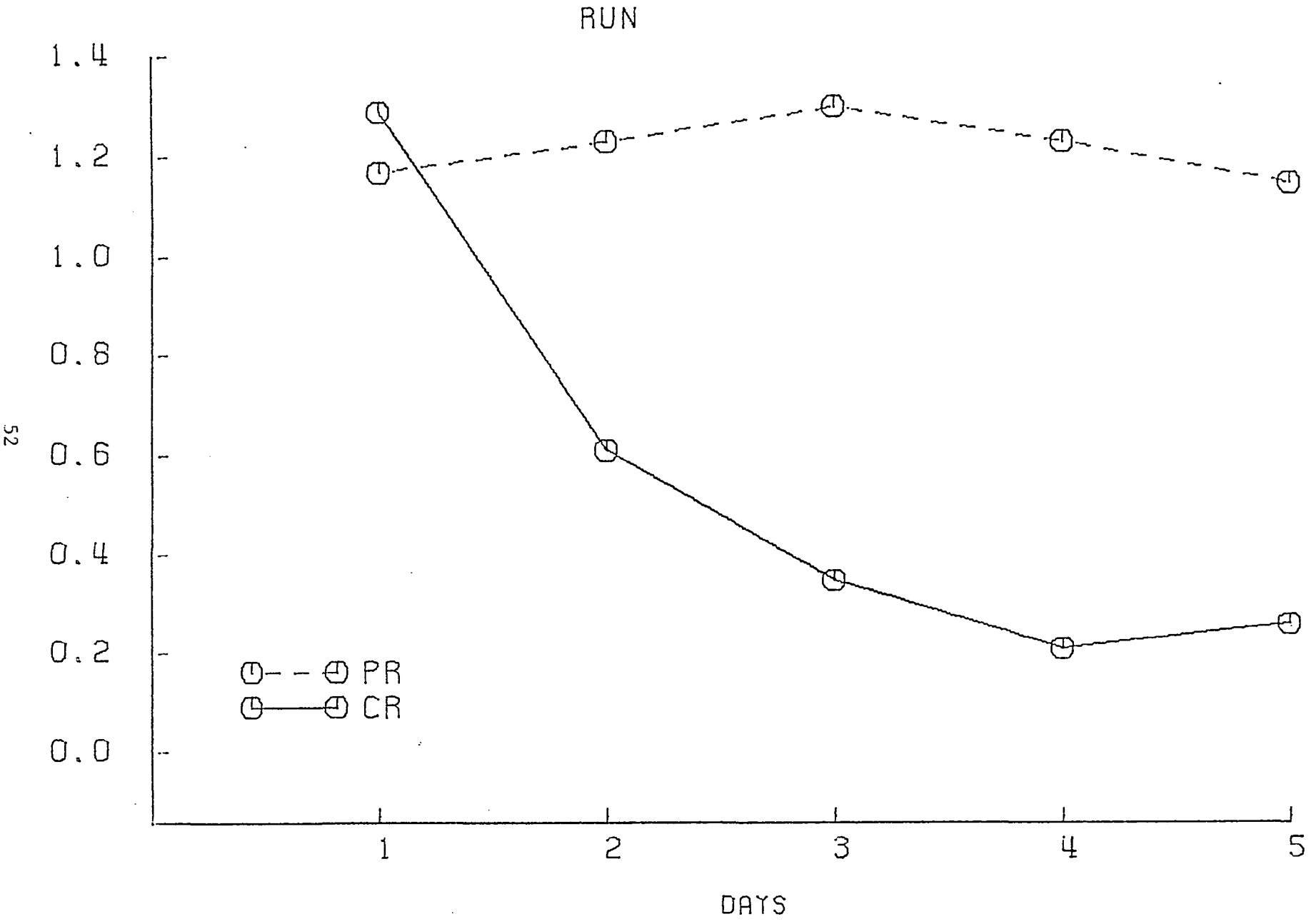
SI
PR
CR
1
2
3
4
5
DAYS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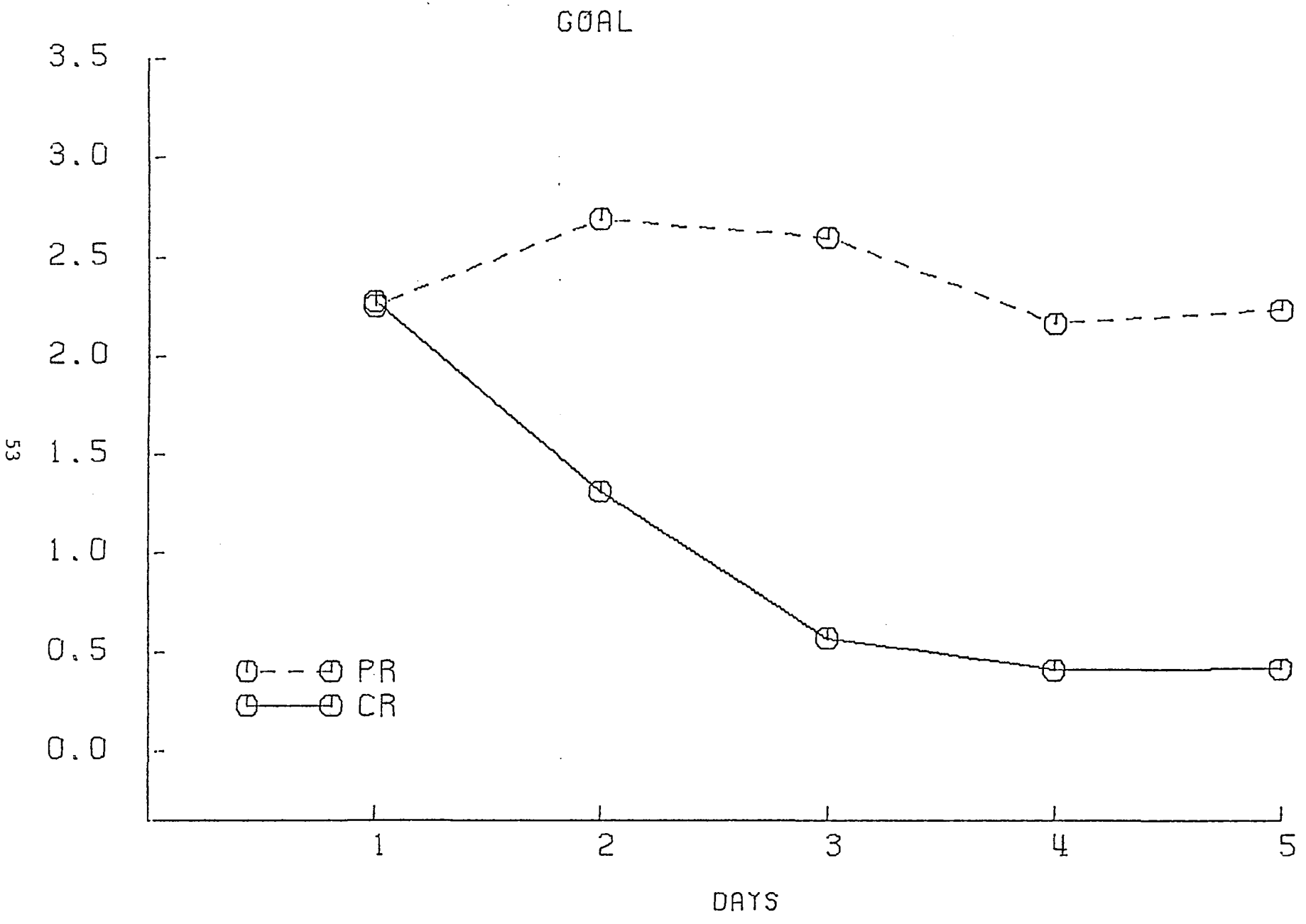
PR
CR
1
2
3
4
5
DAYS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PR
CR
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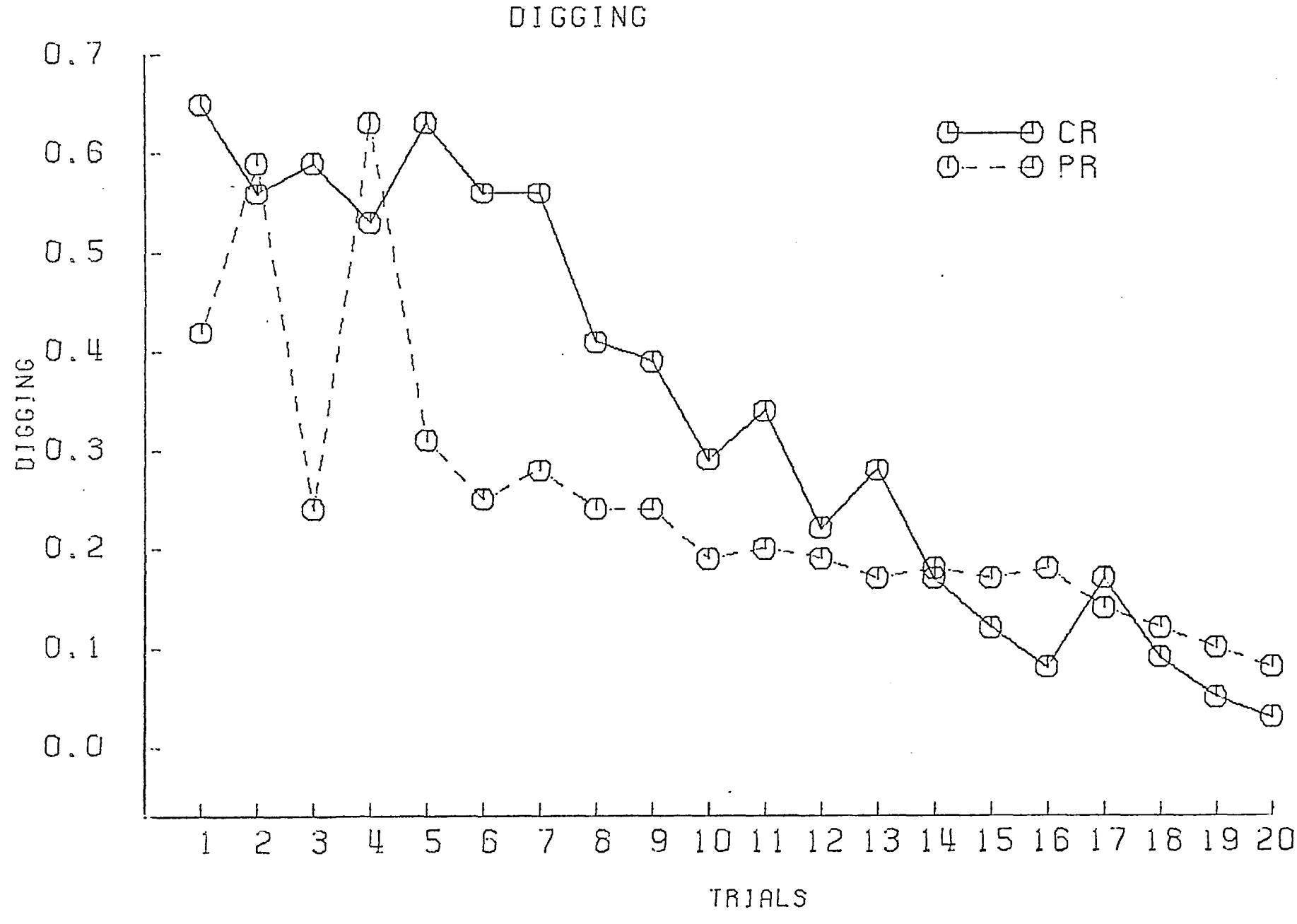
4
5
DAYS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DIGGING
CR
PR
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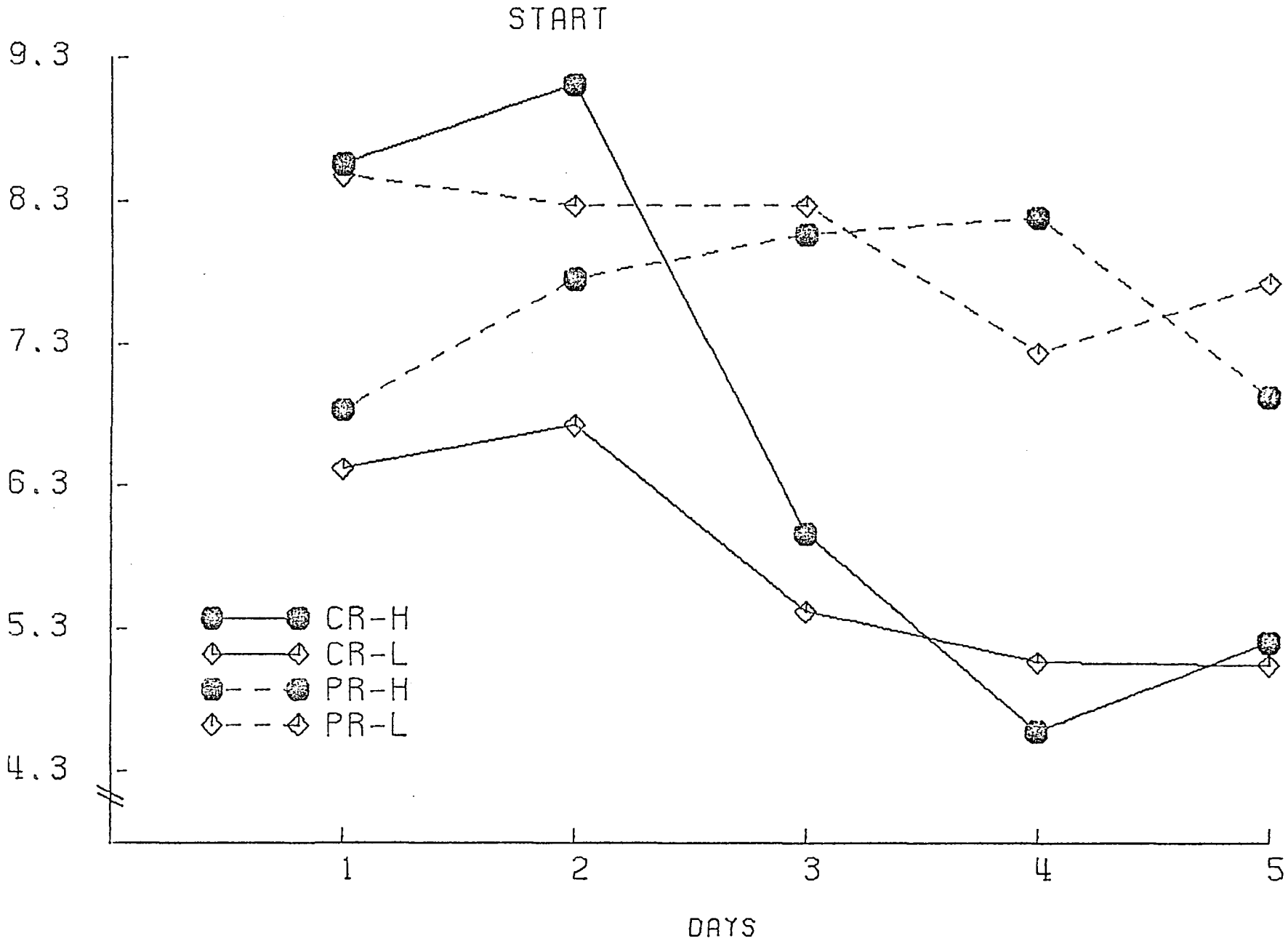
TRIALS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CR-L
PR-H
PR-L
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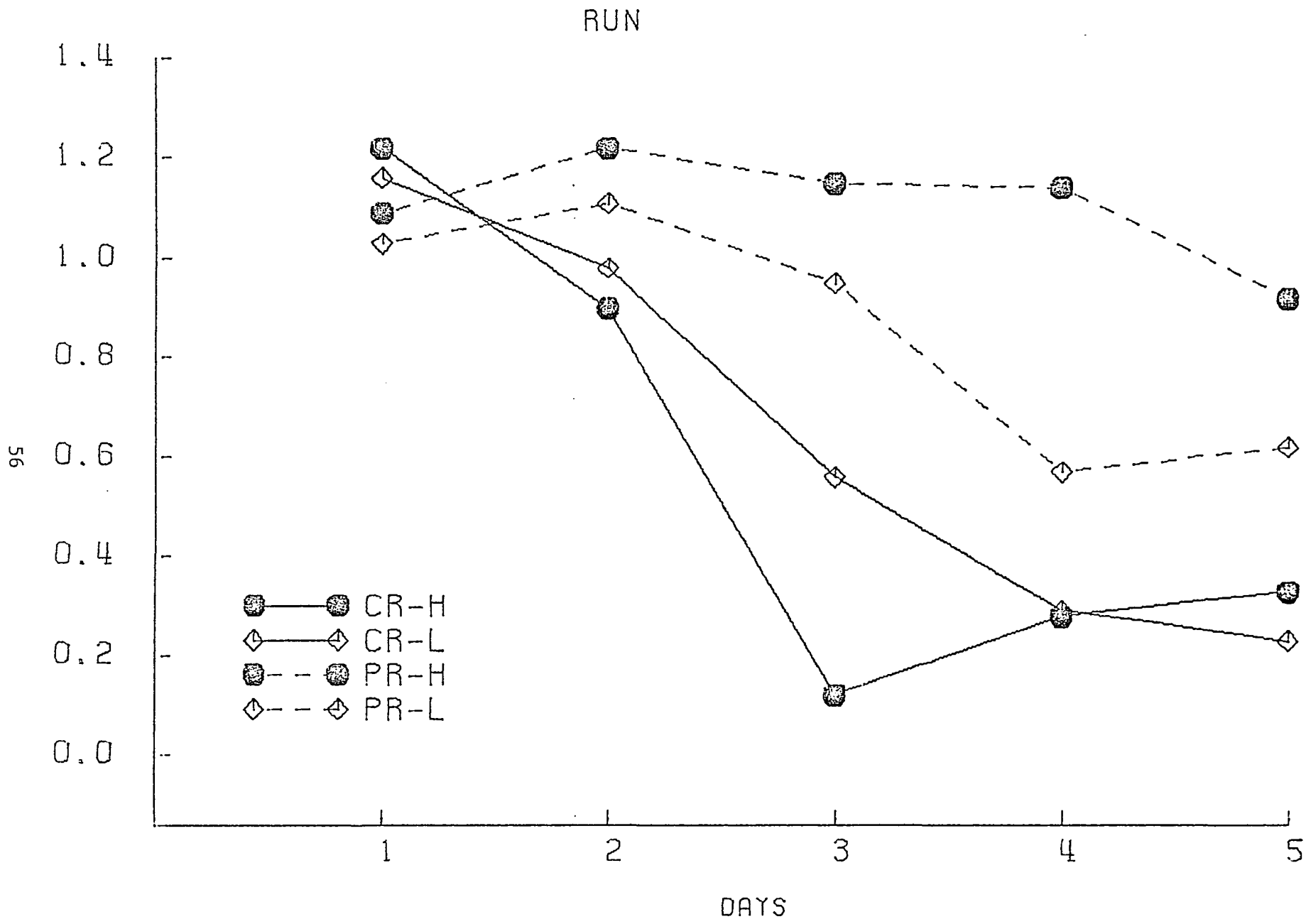
3
4
5
DAYS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PR-L
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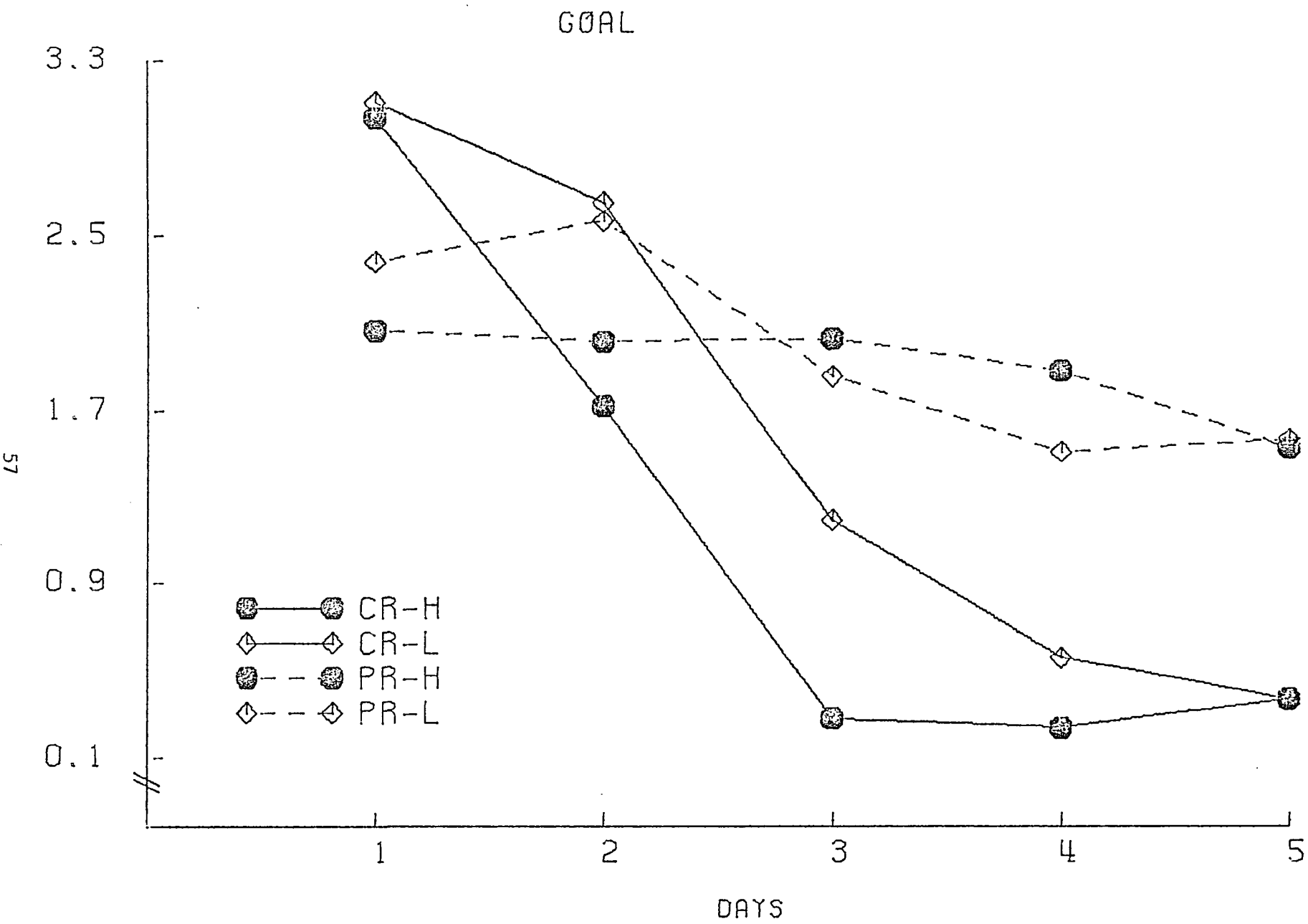
5
DAYS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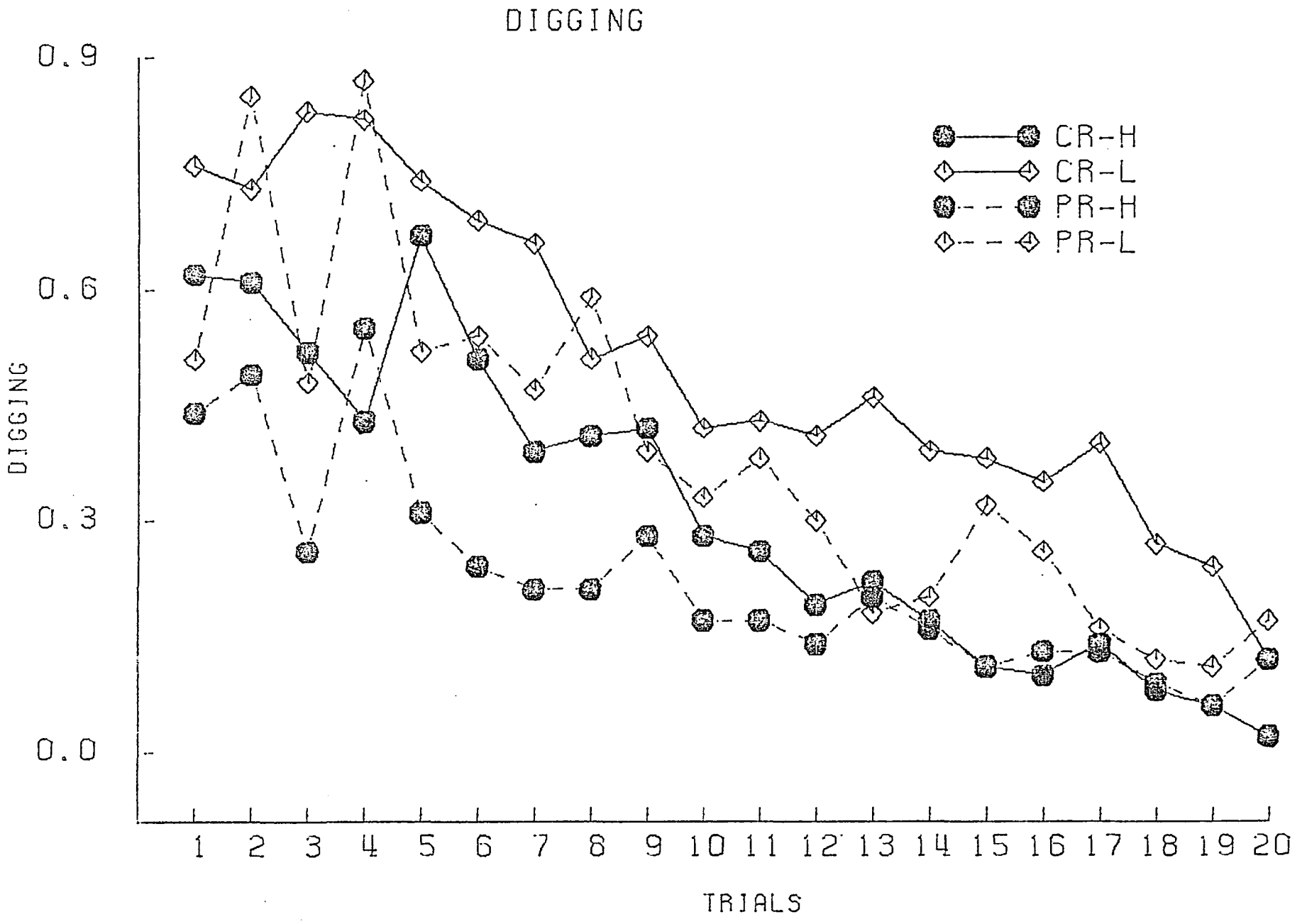
DAYS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DIGGING
CR-H
CR-L
PR-H
PR-L
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TRIALS