# EFFECTS OF MAGNITUDE OF FOOD REINFORCEMENT ON FREE-OPERANT RESPONSE RATES

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In Experiment 1 rats were trained to press a lever on a variable-ratio schedule of food presentation and were then exposed to progressively increasing magnitudes of food reinforcement. Response running rates (rates exclusive of the postreinforcement pause) were found to increase as a function of increasing reinforcement magnitudes. The effect of reinforcement magnitude on response rates inclusive of the postreinforcement pause, however, was less pronounced. Increases in the magnitude of reinforcement were also found to increase the length of the postreinforcement pause. Rats in Experiment 2 were trained to respond on a chained differential-reinforcement-of-low-rate variable-ratio schedule, and were exposed to increasing magnitudes of reinforcement as in Experiment 1. Response running rates increased in the variable-ratio component but decreased in the other component of the schedule. The results are discussed with reference to incentive accounts of reinforcement and the action of reinforcement on the response units generated by the operative contingencies.

*Key words:* reinforcement magnitude, arousal, response shaping, variable ratio, differential reinforcement of low rates, chained schedule, lever press, rats

A substantial number of studies have demonstrated that increasing the magnitude of reinforcement in a runway enhances rats' running speed (see Mackintosh, 1974, pp. 151–154, for a review). Demonstrations showing that performance in a runway is sensitive to changes in reinforcer magnitude are typically viewed in terms of contrast effects. For example, successive positive contrast occurs when increases in the number of food pellets given to hungry rats augment running speed relative to conditions in which there is no change in the magnitude of reinforcement (e.g., Crespi, 1942). These effects have been interpreted in terms of changes in incentive level associated with specific reinforcer magnitudes, and such incentive-produced effects may also be of relevance in explaining the effects of reinforcer magnitude on free-operant responding (e.g., Hull, 1952; Logan, 1960). It has been posited, for example, that reinforcement produces a

general state of arousal (i.e., increases overall levels of activity), and that this state can serve to energize the level of instrumental performance (Killeen, 1979). The greater the magnitude of the reinforcement, the greater the state of arousal, and hence, the more behavior that is emitted (Killeen, 1985).

Although the effects of the magnitude of reinforcement on free-operant choice, especially in relation to delayed reinforcement, have been extensively investigated (e.g., Green & Synderman, 1980), the effects of different magnitudes of reinforcement on response rates per se have only rarely been examined (e.g., Harzem, Lowe, & Priddle-Higson, 1978; Keesey & Kling, 1961). This stands in marked contrast to the literature examining reinforcer magnitude in a runway. Furthermore, despite the seemingly unambiguous relationship obtained in a runway between reinforcer magnitude and running speed, those studies that have examined the effect of reinforcer magnitude on free-operant response running rates have rendered a confused pattern of results (cf. Harzem et al., 1978; Powell, 1969).

In apparent contrast to the findings in a runway, it has been reported by Harzem et al. (1978) that increasing the reinforcer size may decrease response rates in the operant conditioning chamber. Harzem and Harzem (1981) interpreted this decrease in rate as being due to unconditioned inhibitory properties of the

reinforcer. According to their account, such inhibitory properties are manifest in the pause from responding following the delivery of the reinforcer, the length of the pause increasing as a function of reinforcement magnitude. Hence, a possible reason for the discrepancy between the findings generated in the runway and in the operant chamber is that the response rate measure taken differs between the two paradigms. In the runway the postreinforcement pause (i.e., latency to commence running) usually is not taken into account when calculating running speeds, as this period is likely to be spent in the startbox or is taken up in the intertrial interval.

The failure to demonstrate unambiguous results with changes in reinforcer magnitude in a free-operant situation, in contrast to the more successful work using the runway, poses a problem for any general unitary-process account of such effects. The aim of the present experiments was to investigate the influence of reinforcement magnitude on response running rates generated by schedules of reinforcement of a free operant.

## EXPERIMENT 1

In Experiment 1 we investigated the effects of increasing the reinforcer magnitude on responding maintained by a variable-ratio (VR) schedule. The plan was to examine the sustained effects of reinforcer magnitude on response running rate, so amounts of reinforcers were accordingly presented in successively increasing quantities across blocks of sessions before returning subjects to baseline conditions. Within-session variations of reinforcer magnitude, which are commonly used in this type of study, are known to enhance the inhibitory effect of reinforcement. That is, the length of the postreinforcement pause is increased (see Harzem, Lowe, & Davey, 1975). To avoid the influence of such inhibitory effects, and also to avoid any confound with increased consummatory time correlated with greater magnitudes of reinforcement, the response rates after the postreinforcement pause (i.e., response running rates) were analyzed in addition to the overall response rate. The former measure also allowed a more direct comparison with studies carried out in the runway which typically do not take into account the postreinforcement pause.

## METHOD

### Subjects

Four experimentally naive, male Lister hooded rats, approximately 4 months old at the start of the experiment, were used. They were maintained at 85% of their free-feeding body weights, individually housed, and had water constantly available in the home cage. The vivarium was maintained on a 16:8 hr light/dark cycle.

### Apparatus

One operant conditioning chamber (Campden Instruments Ltd., model 410) housed in a sound- and light-attenuating chest was used. A ventilating fan provided a 65-dB(A) (re.SPL) background masking noise. The chamber was equipped with two retractable response levers positioned 5 cm above the grid floor and 11 cm apart. Reinforcers were 45-mg Noyes food pellets delivered to a food tray located midway between the two levers. The chamber was not illuminated during the experiment.

### Procedure

The subjects were first placed in the chamber and allowed 1 hr to adapt to the apparatus. During this time both levers were retracted and the animal was allowed free access to the food tray, which was filled with pellets. After the subjects were consistently eating the pellets, the left lever was inserted into the chamber; the other remained withdrawn for the duration of the study. The animals were trained to press the lever, during four sessions in which every press was reinforced. Each session lasted until the 30th reinforcer was delivered. Following this treatment, all animals were exposed to fixed-ratio (FR) schedules of reinforcement that increased in requirement in units of five responses from an FR 5 to an FR 30. A subject remained at a ratio-schedule value until it had completed three successive 30-pellet sessions in progressively decreasing session durations. Pretraining lasted for 35 sessions. When pretraining was completed, the critical experimental contingencies were introduced.

All subjects were exposed to a VR-30 schedule (range of ratios: 1 to 59) throughout the critical phase of the experiment, each session lasting until 30 reinforcements had occurred. All subjects were exposed to all reinforcement-magnitude conditions. These conditions were

deliveries of one, two, three, and four pellets per schedule completion; the conditions occurred in four successive stages. When more than one pellet was administered following the criterion response, the pellets were delivered at the rate of one per 100 ms. Each subject was exposed to the one-pellet condition for 20 sessions, and thereafter to each of the three subsequent (greater) reinforcement-magnitude conditions for 15 sessions. Following the 15 sessions of exposure to the four-pellet condition, subjects were returned to the baseline condition of one pellet per reinforcement for an additional 15 sessions.

## RESULTS AND DISCUSSION

Results are based on the data obtained from the last 6 days in each experimental phase of the study. Response running rates generated over the last six sessions in each reinforcement-magnitude condition are displayed in Figure 1. This measure was calculated by subtracting the latency to the first response following each reinforcement from the total session time before calculating response rate.

The data shown in Figure 1 reflect stable performance in each of the conditions, for response running rates satisfied a stability criterion of not varying by more than 15% from session to session. Furthermore, the response running rates across the terminal sessions within each phase demonstrated no systematic trend. The rates reflecting these terminal levels of performance, however, did increase over the course of exposure to each magnitude condition. The results depicted in Figure 1 demonstrate a general increase in running rate with higher reinforcement magnitudes. The mean scores produced by pooling the response running rates for each phase were 49 responses per minute for the one-pellet condition and 64, 71, and 80 responses per minute for the two-, three-, and four-pellet conditions, respectively. The return to baseline conditions resulted in a mean response running rate of 57 responses per minute.

Subjects R1 and R4 displayed an increasing response running rate across all increases in magnitudes of reinforcement. In contrast, for Subjects R2 and R3 the effect of the increment in reinforcement magnitude was an increase in response running rate for a single-magnitude condition. Subject R2 demonstrated an increase in response running rate upon the

transition from one to two pellets per reinforcement, and Subject R3 displayed the most pronounced increase in response running rate on the transition from two to three pellets. For these 2 subjects (R2 and R3), once this increase had occurred, further transitions to higher magnitudes had little effect. Returning the animals to the one-pellet baseline condition decreased response running rate to a level comparable with that observed in the first phase of the study.

Figure 2 displays the overall response rates (i.e., the response rate generated when the pause following reinforcement was included in the calculation) over the last six sessions in each reinforcement-magnitude condition. Inspection of these data reveals that the overall response rates follow the same pattern as the response running rates depicted in Figure 1; that is, the overall response rates increased with higher reinforcement magnitudes. The mean scores produced by pooling the response rates for each phase were 45 responses per minute for the one-pellet condition and 61, 66, and 70 responses per minute for the two-, three-, and four-pellet conditions, respectively. The return to baseline conditions resulted in a mean overall rate of 53 responses per minute. However, this increasing trend with greater magnitudes of reinforcement is not as clear as that generated with response running rates. Subject R1 displayed an increasing overall response rate across all increases in reinforcement magnitude, whereas for Subject R2 the effect of the increment in reinforcement magnitude was manifest in an increase for a single magnitude condition. Subject R3 increased response rate on the transition from two to three pellets per reinforcer. Subject R4 displayed a less pronounced increase in rate with increases in reinforcement magnitude than that which it had displayed when rates were calculated without the postreinforcement pause. This slightly more ambiguous effect of reinforcement magnitude is consistent with the findings of Powell (1969), who reported little effect of reinforcement magnitude on the performance of pigeons on an FR schedule.

The mean postreinforcement pause computed over the final six sessions at each reinforcement-magnitude condition is displayed for each subject in Figure 3. Inspection of these data reveals that increasing postreinforcement pauses resulted from greater magnitudes of
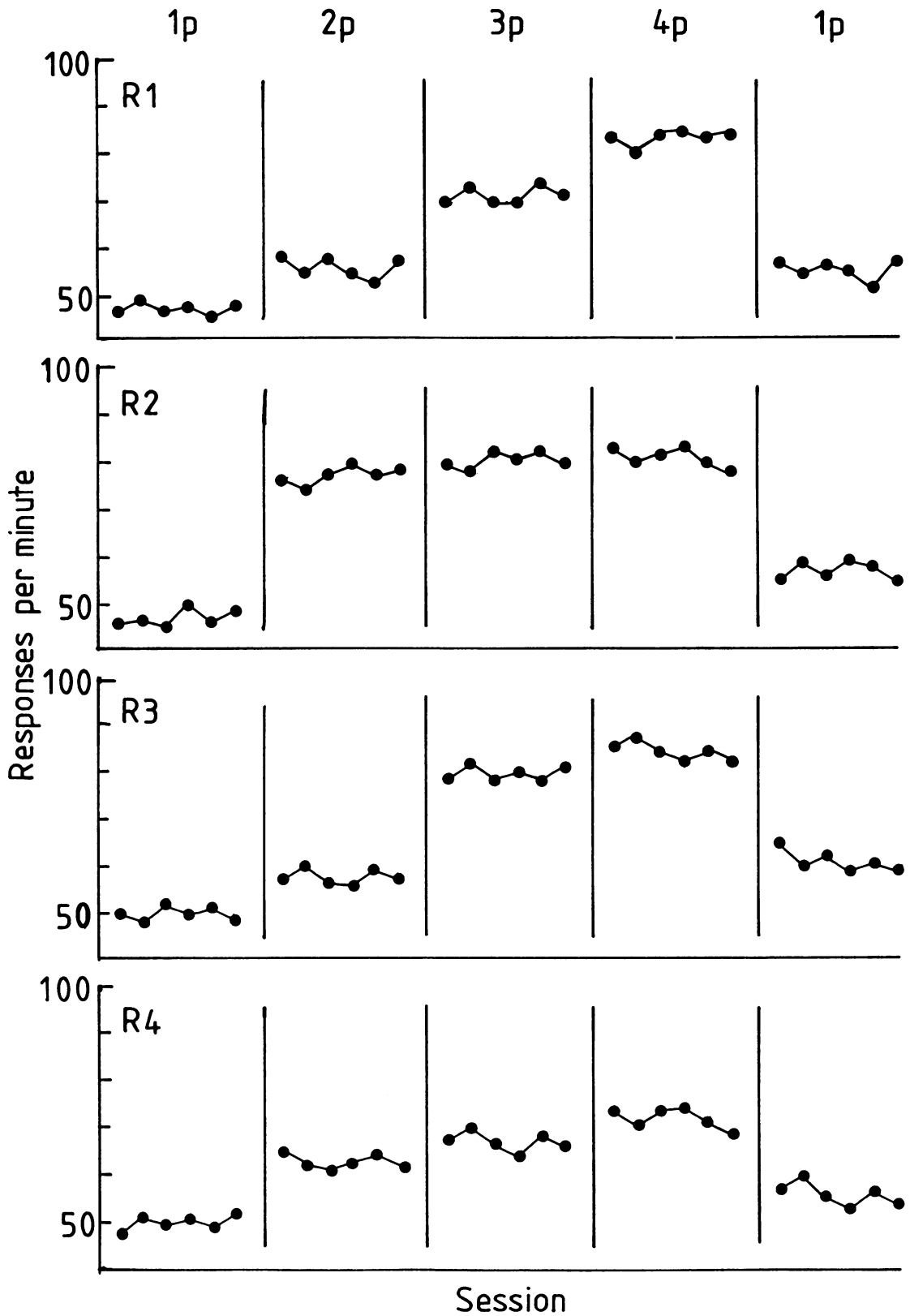
Fig. 1.    Response running rate in the VR schedule for all subjects, computed over the last six sessions of each reinforcement-magnitude condition (p = pellets per reinforcement).
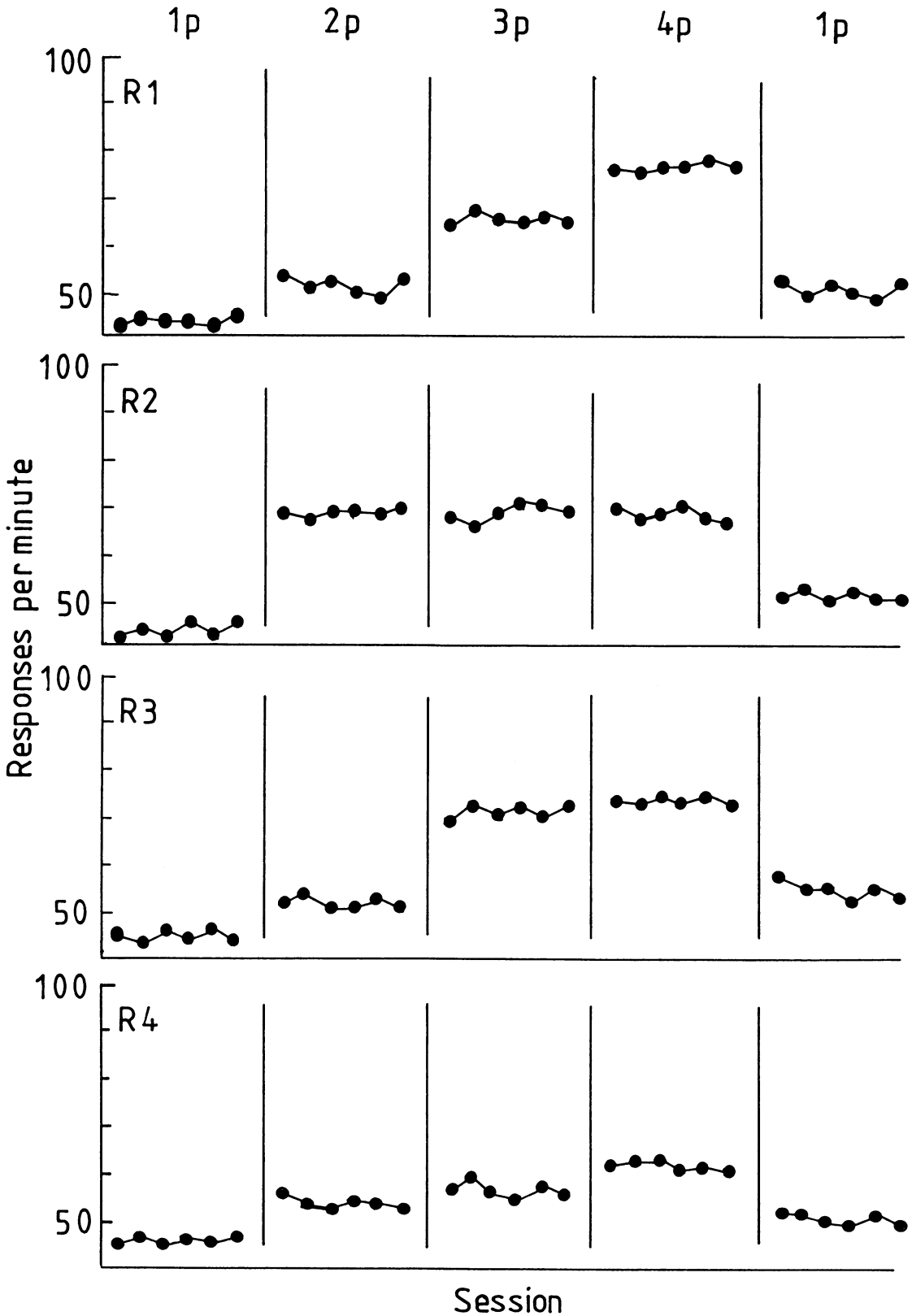
Fig. 2. Overall response rates in the VR schedule for all subjects, computed over the last six sessions of each reinforcement-magnitude condition (p = pellets per reinforcement).
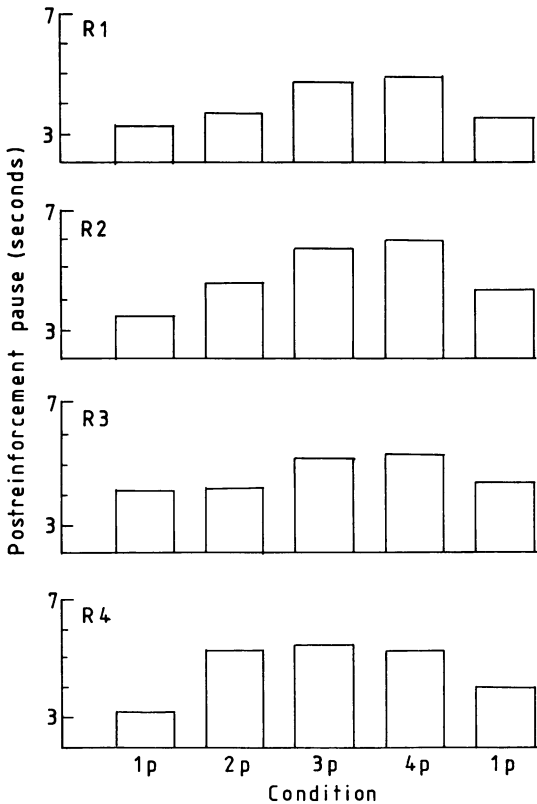
Fig. 3.    Mean postreinforcement pause for all subjects, computed over the last six sessions of each reinforcement-magnitude condition (p = pellets per reinforcement).

reinforcement. This is consistent with the effect reported by Harzem et al. (1978), although it should be noted that the present data may simply reflect increased consumption time correlated with larger numbers of food pellets. Nevertheless, these findings may provide an explanation for the difference between the results obtained when response running rate, compared to overall response rate, was taken as a measure of the effect of reinforcement magnitude (see also Harzem & Harzem, 1981). Because greater magnitudes of reinforcement resulted in longer postreinforcement pauses, the increase in running rate was partly balanced out and this effect was consequently less evident in overall response rate. Hence, when overall rates are considered, magnitude of reinforcement appears to have smaller, or even inconsistent effects. Given the measure of response rate taken in the runway, and that usually reported for the operant conditioning chamber, a similar phenomenon may account

for the disparity between the two paradigms regarding the effect of amount of reinforcement.

The demonstration of elevated response running rates generated by increased reinforcement magnitudes on a VR schedule prompts a consideration of putative causes of this effect. Greater reinforcement magnitude may have increased the general level of activity (i.e., arousal levels) which thereby increased the vigor of responding (cf. Logan, 1960; Spence, 1956). Explanations that give a role to a general arousing effect of reinforcement have also been advanced by Killeen (1979, 1982). An alternative potential factor underlying the present results is derived from the analysis of schedule performance advanced by Ferster and Skinner (1957). This notion proposes that the reinforcer acts to strengthen the response topography that is generated by the operative schedule contingency. These processes that might account for enhanced responding generated by increases in reinforcement magnitude are addressed in Experiment 2.

## EXPERIMENT 2

Experiment 1 demonstrated that larger magnitudes of reinforcement have a facilitating effect on the response running rates generated by a VR schedule. This could be attributed to an enhanced general level of excitation produced by increasing reinforcement magnitudes. Such an account predicts that an overall enhancement of response rates should be evident even on a schedule that requires responding to be withheld for a period of time for reinforcement to occur—a schedule that differentially reinforces low response rates. This possibility was tested using a chained schedule in which one component was a VR and the other a differential-reinforcement-of-low-rate (DRL) schedule. If the two distinct topographies of responding generated by such schedules are differentially affected, that is, if the behavior during the VR component is enhanced and that during the DRL component is attenuated as greater magnitudes of reinforcement are delivered, some support would be given to the notion that reinforcement increases the probability of the emission of the defined operant response unit. The present experiment may serve to distinguish an in-

creased-arousal interpretation of the results of Experiment 1 from an account that considers the pattern of responding that may be reinforced on the various schedules.

## METHOD

### Subjects and Apparatus

Four experimentally naive, male Lister hooded rats were maintained as described for Experiment 1. The apparatus was the same as that used in Experiment 1, except that the two small houselights located 4 cm above each lever provided discriminative stimuli.

### Procedure

The details of the initial pretraining were the same as in Experiment 1. In the session following the FR-30 pretraining phase, a chained DRL VR-30 schedule was introduced. This schedule was arranged as follows: The session commenced with insertion of the right response lever, for which the DRL schedule was operative, accompanied by the illumination of a white, flashing (500-ms on, 500-ms off), jeweled houselight, located above the right lever. Thus, the white flashing light served as a discriminative stimulus ($S^D$) for the DRL schedule. When the operative DRL criterion was satisfied, the lever retracted, the white light was extinguished, and the left lever was immediately inserted into the chamber. The bright, steady, white houselight located above this lever was illuminated and a VR schedule was now in effect. When the VR-30 schedule requirement (range: 1 to 59) was completed, the left response lever was retracted and the stimulus extinguished immediately before the reinforcer was delivered. Both levers remained out of the chamber for 3 s before the right lever was reinserted and the flashing houselight illuminated to commence the next DRL component.

The DRL contingency was programmed to operate as described below. To initiate the DRL time requirement the subject had to make a response. Reinforcement was delivered if the subject then withheld responding until after the specified time period had elapsed. Any response before the required interval had elapsed reset this schedule requirement; that is, the subject had to respond and then withhold further responses for the criterion time. The use of a response-initiated DRL schedule separated the postreinforcement pause from the performance generated by the DRL contingency, and hence, prevented longer consumption times correlated with larger reinforcement magnitudes from possibly confounding the response rates. The use of a chained schedule ensured that this factor would not similarly confound the results from the VR component.

Pretraining for the DRL schedule began after the introduction of the chained schedule. Initially, five sessions of an FR-2 (i.e., DRL 0 s) schedule were given as the first component of the chain. Following this, four sessions of a DRL 4-s schedule were given. The DRL requirement was subsequently increased to 6 s and then to 8 s for five and six sessions, respectively. Shaping of performance under the DRL schedule was complete within 20 days. The complete pretraining procedure lasted 48 days.

The critical phase of the study consisted of delivering reinforcers upon completion of a chained DRL 10-s VR-30 schedule. Each session lasted until the 15th reinforcement. Thus, there were 15 exposures to each of the individual components of the chained schedule during a session. The number of sessions of exposure to each reinforcement-magnitude condition was the same as in Experiment 1.

## RESULTS AND DISCUSSION

The results are based on data from the last 6 days in each experimental phase of the study. Figure 4 shows response running rates for each of the subjects in both components of the schedule. For the DRL component, response running rate was calculated by taking the time from the first response to the emission of the appropriate interresponse time (IRT) (i.e., until the VR schedule component commenced). For the VR schedule the running rate was calculated by discounting the interval from the onset of the VR schedule to the first response.

It is clear that increasing the magnitude of reinforcement in the VR-30 component generated faster response running rates in 3 of the 4 animals. The mean of the response running rates generated by all animals in the six sessions of the one-pellet condition was 55 responses per minute. This mean increased to 61 responses per minute for the two-pellet condition and subsequently to 66 and 71 responses per minute for the three- and four-pellet conditions, respectively. The final
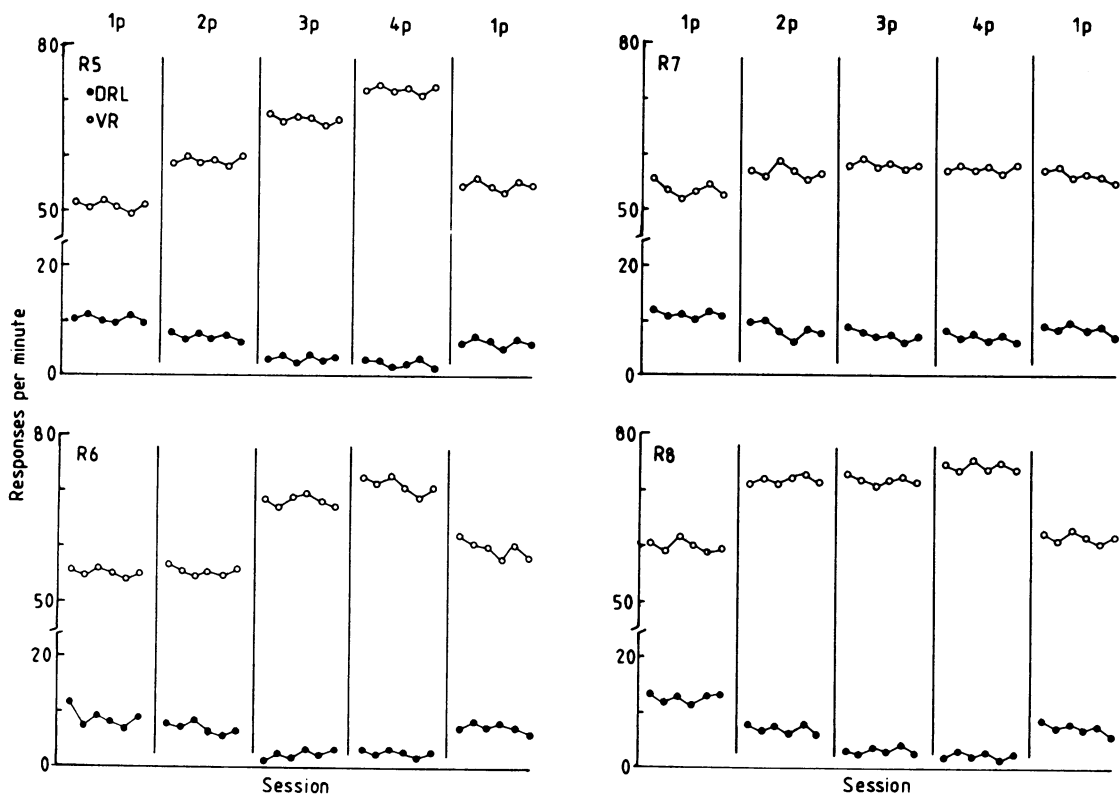
Fig. 4. Response running rates in both the VR (open circles) and DRL (solid circles) schedule components of Experiment 2. Data are taken from the last six sessions of each reinforcement-magnitude condition (p = pellets per reinforcement).

baseline conditions resulted in a mean response running rate of 58 responses per minute. Subject R7 did not display this pattern. For this subject increases in reinforcement magnitude appeared to have little influence on response running rates. However, the remaining 3 animals did display increasing response running rates with increasing reinforcement magnitudes. Subject R5 showed elevated response running rates on each transition, whereas Subjects R6 and R8 displayed an increase in running rate following one transition in reinforcement magnitude. This elevation for Subjects R6 and R8 was followed by little additional increase across subsequent phases. As in Experiment 1, returning to the one-pellet condition decreased the response rates to a level comparable to those obtained in the initial one-pellet phase. The general pattern of results thus replicated that found in Experiment 1 with a simple VR schedule.

The data obtained for the DRL 10-s component stand in marked contrast to those ob-

tained in the VR-30 component of the chained schedule. Response running rates gradually decreased with increases in reinforcement magnitude except for Subject R7, which displayed only slight decreases in rate. Returning to the baseline condition of one pellet per reinforcement tended to restore response running rates to a level comparable to that of the one-pellet condition in Phase 1. Mean response running rates, pooled for all animals, from this component of the chained schedule were 11, 8, 4, and 4 responses per minute for the one-, two-, three-, and four-pellet conditions, respectively. Returning to the one-pellet condition resulted in an increased mean response running rate of 9 responses per minute.

Figure 5 shows, for each subject, the mean postreinforcement pause (i.e., the time to commence the DRL component after insertion of the lever) over the final six sessions at each reinforcement-magnitude condition. Inspection of these data reveals that increasing postreinforcement pauses resulted from greater

magnitudes of reinforcement. This is consistent with the effect noted in Experiment 1. Although it should be noted that this may simply be due to increased consumption time as the magnitude of reinforcement was increased, the presence of a 3-s timeout that followed food presentation makes this account unlikely as a full explanation of the effect. Harzem and Harzem (1981) suggested that increased post-reinforcement pauses result from greater reinforcement magnitudes caused by an increased inhibitory effect of the greater reinforcement. The present results are consistent with this view. Response rates in the VR component are obviously not affected by inclusion of the postreinforcement pause. The result of including this period in the calculation of overall response rates for the DRL schedule is to lower the rates. The group mean overall DRL response rates at the different levels of reinforcement magnitude were 10, 7, 4, and 3 responses per minute for the one-, two-, three-, and four-pellet conditions, respectively. The pattern of results over the terminal sessions of each phase is the same as the pattern when the postreinforcement pause is excluded.

To summarize the results from Experiment 2, greater magnitudes of reinforcement were accompanied by an increase in response running rate with extended training on VR schedules. Additionally, it was demonstrated that increases in reinforcement magnitude can act to "enhance" DRL performance, that is, to decrease the response running rate. It was further noted that, as in Experiment 1, increases in reinforcement magnitude induced increases in the length of the postreinforcement pause. The results are consistent with the notion that the effect of reinforcement magnitude is dependent on the specific behavior being emitted at the time of reinforcement, rather than a general increase of responding. The enhancement of performance on the DRL schedule is consistent with the view that the structure of the behavior emitted during this schedule (i.e., long interresponse times) is strengthened in proportion to the reinforcement magnitude.

Beer and Trumble (1965) assessed the influence of reinforcement magnitude on DRL performance. They found that DRL performance was less efficient; that is, the number of responses per reinforcement was higher with larger magnitudes of reinforcement. This re-
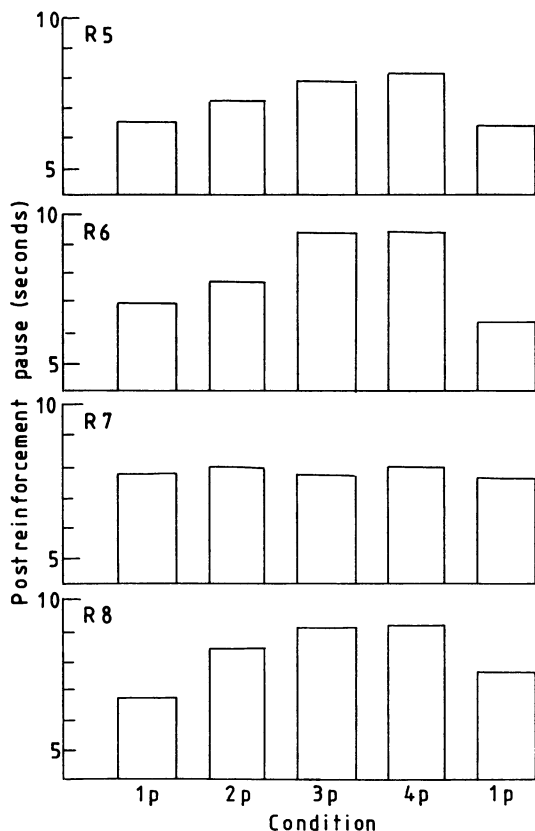


Fig. 5. Mean postreinforcement pause for all subjects, computed over the last six sessions of each reinforcement-magnitude condition (p = pellets per reinforcement).

sult stands in contrast to the present findings. However, there are a number of differences between the present study and that of Beer and Trumble (1965) that make direct comparison difficult. The differences in results may have arisen from the use of between-sessions design in the present experiment whereas Beer and Trumble (1965) gave subjects different concentrations of a sucrose solution within a session. The within-session procedure, as discussed previously, is known to produce different effects on responding than when reinforcement magnitude is altered between sessions (see Harzem et al., 1975).

It must be acknowledged, however, that the use of a chained schedule in the present study does pose some problems for the interpretation of the data. The consequence of emitting an IRT of the appropriate length in the first component of the chain was the presentation of the VR component signaled by a stimulus change. Although it is not unreasonable to as-

sume that the presentation of the stimuli correlated with the VR schedule was more effective as a conditioned reinforcer when more food was earned via the VR schedule (see D'Amato, 1955), this still remains an assumption. Consequently, the comparison made in the present study is between the effects of changes in unconditioned (or primary) reinforcement and changes in conditioned reinforcement. Another possible source of influence that arises by the use of a chained schedule is the possibility that behavioral contrast could have contributed to the results. The increased magnitude of reinforcement under the VR schedule may have, via contrast, lowered rates during the DRL component. The present data may give some support to this conclusion. For example, under the four-pellet condition the group mean response rate fell to four responses per minute; this is quite a low rate for responding under a DRL 10-s schedule (cf. Richardson, 1973).

## GENERAL DISCUSSION

Experiment 1 demonstrated a positive relationship between the response running rate generated by a VR schedule and the increase in reinforcement magnitude. This finding was confirmed by the results from the VR component of Experiment 2. Experiment 2 also found that response rates on a DRL schedule were reduced when the completion of the DRL requirement initiated a VR schedule with a larger reinforcement magnitude. The effect of increasing magnitudes of reinforcement on the postreinforcement pause noted in the present study suggests a point of discrepancy between runway and operant-conditioning-chamber procedures. The postreinforcement pause is not usually included in calculations of running speeds in an alleyway. When it is likewise removed from the calculation of response rates in the operant conditioning chamber a more substantial effect on rate is observed (see also Harzem et al., 1978).

There could, of course, be multiple determinants of the present results. For example, the possible influence of behavioral contrast in producing the results generated in Experiment 2 has been noted; hence, any account of the data must be tempered in light of this possibility. Nevertheless, a possible interpretation suggested by the data concerns the interaction

of reinforcement magnitude and the pattern of responding typically reinforced on the operative schedule. This view can account for the results generated in the present experiments if it is assumed that the dominant behavioral topography (i.e., the total behavioral sequence that serves as the operant) will come to be emitted more frequently as a function of larger reinforcement magnitudes. On a DRL schedule the dominant topography might include collateral behavior patterns that may also be increased in frequency as the magnitude of reinforcement increases. Hence, the observed response running rate would decrease, a result obtained in our Experiment 2. The determinants of such behavioral units include the frequency with which one specific unit is reinforced by a particular schedule and subsequently gains strength (Anger, 1956), the schedule presently in operation (Ferster & Skinner, 1957), and the contingencies previously experienced by the animal (Logue, Rodriguez, Peña-Correal, & Mauro, 1984).

Support for an interactional interpretation of reinforcer effectiveness, a notion proposed by Henton and Iversen (1978), can be found in a variety of other preparations. Cognitive theories of reinforcement-magnitude effects (e.g., Bolles, 1972; Trapold & Overmier, 1972) have proposed that specific anticipatory responses may be differentially conditioned to different reinforcement values (e.g., Spence, 1956). Such conditioning can, for example, create different patterns of lever approach (Carlson & Wielkiewicz, 1976; see also Burns, 1976, for an example of differential patterns of behavior in the runway after different reinforcement magnitudes). The suggestion that different magnitudes of reinforcement can act as discriminative stimuli for the emission of different specific patterns of responding is also documented in the operant conditioning literature (Cruse, Vitulli, & Dertke, 1966). If the structure of behavior interacts with reinforcement magnitude, molar contingency theories of the action of reinforcement, such as those proposed by Baum (1973), may have to be modified to consider the effect of reinforcement on the local structure of behavior.

## REFERENCES

Anger, D. (1956). The dependence of interresponse times upon the relative reinforcement of different interresponse times. *Journal of Experimental Psychology,* **52,** 145–161.

Baum, W. M. (1973). The correlational-based law of effect. *Journal of the Experimental Analysis of Behavior,* **20,** 137–153.

Beer, B., & Trumble, G. (1965). Timing behavior as a function of amount of reinforcement. *Psychonomic Science,* **2,** 71–72.

Bolles, R. C. (1972). Reinforcement, expectancy, and learning. *Psychological Review,* **79,** 394–409.

Burns, R. A. (1976). Effects of sequences of sucrose reward magnitudes with short ITIs in rats. *Animal Learning & Behavior,* **4,** 473–479.

Carlson, J. G., & Wielkiewicz, R. M. (1976). Mediators of the effects of magnitude of reinforcement. *Learning and Motivation,* **7,** 184–196.

Crespi, L. P. (1942). Quantitative variation of incentive and performance in the white rat. *American Journal of Psychology,* **55,** 467–517.

Cruse, D. B., Vitulli, W., & Dertke, M. (1966). Discriminative and reinforcing properties of two types of food pellets. *Journal of the Experimental Analysis of Behavior,* **9,** 293–303.

D'Amato, M. R. (1955). Secondary reinforcement and magnitude of primary reinforcement. *Journal of Comparative and Physiological Psychology,* **48,** 378–380.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Green, L., & Snyderman, M. (1980). Choice between rewards differing in amount and delay: Toward a choice model of self control. *Journal of the Experimental Analysis of Behavior,* **34,** 135–147.

Harzem, P., & Harzem, A. L. (1981). Discrimination, inhibition, and simultaneous association of stimulus properties: A theoretical analysis of reinforcement. In P. Harzem & M. D. Zeiler (Eds.), *Advances in analysis of behaviour: Vol. 2. Predictability, correlation, and continuity* (pp. 81–124). Chichester, England: Wiley.

Harzem, P., Lowe, C. F., & Davey, G. C. L. (1975). After-effects of reinforcement magnitude: Dependence upon context. *Quarterly Journal of Experimental Psychology,* **27,** 579–584.

Harzem, P., Lowe, C. F., & Priddle-Higson, P. J. (1978). Inhibiting function of reinforcement: Magnitude effects on variable-interval schedules. *Journal of the Experimental Analysis of Behavior,* **30,** 1–10.

Henton, W. W., & Iversen, I. H. (1978). *Classical conditioning and operant conditioning: A response pattern analysis.* New York: Springer-Verlag.

Hull, C. L. (1952). *A behavior system.* New Haven, CT: Yale University Press.

Keesey, R. E., & Kling, J. W. (1961). Amount of reinforcement and free-operant responding. *Journal of the Experimental Analysis of Behavior,* **4,** 125–132.

Killeen, P. R. (1979). Arousal: Its genesis, modulation, and extinction. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol 1. Reinforcement and the organization of behaviour* (pp. 31–78). Chichester, England: Wiley.

Killeen, P. R. (1982). Incentive theory. In D. J. Bernstein (Ed.), *Nebraska symposium on motivation 1981: Vol. 29. Response structure and organization* (pp. 169–216). Lincoln: University of Nebraska Press.

Killeen, P. R. (1985). Incentive theory: IV. Magnitude of reward. *Journal of the Experimental Analysis of Behavior,* **43,** 407–417.

Logan, F. A. (1960). *Incentive.* New Haven, CT: Yale University Press.

Logue, A. W., Rodriguez, M. L., Peña-Correal, T. E., & Mauro, B. C. (1984). Choice in a self-control paradigm: Quantification of experience-based differences. *Journal of the Experimental Analysis of Behavior,* **41,** 53–67.

Mackintosh, N. J. (1974). *The psychology of animal learning.* London: Academic Press.

Powell, R. W. (1969). The effect of reinforcement magnitude upon responding under fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior,* **12,** 605–608.

Richardson, W. K. (1973). A test of the effectiveness of the differential-reinforcement-of-low-rate schedules. *Journal of the Experimental Analysis of Behavior,* **20,** 385–391.

Spence, K. W. (1956). *Behavior theory and conditioning.* New Haven, CT: Yale University Press.

Trapold, M. A., & Overmier, J. B. (1972). The second learning process in instrumental learning. In A. H. Black & W. F. Prokasy (Eds.), *Classical Conditioning II: Current research and theory* (pp. 427–452). New York: Appleton-Century-Crofts.