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Effects of the Manipulation of the Range of the Variable-Ratio Components of a Multiple Schedule Upon Response Rate and Post-Reinforcement Pause.

by

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"EFFECTS OF THE MANIPULATION OF THE RANGE OF THE VARIABLE-RATIO COMPONENTS OF A MULTIPLE SCHEDULE UPON RESPONSE RATE AND POST-REINFORCEMENT"

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ABSTRACT

Eight hooded rats were exposed to a multiple schedule of positive reinforcement with three variable ratio (VR) components. The mean of these VR components was equal but the range (rg) over which they varied was different. The specific values were: VR30, rg11 (25-35); VR30, rg31 (15-45); VR30, rg51 (5-55). During the baseline all components were VR30, rg1 (i.e., a fixed ratio of 30). The components were then switched to the three component multiple schedule specified above. Subjects were then exposed to extinction conditions in all three components simultaneously (i.e., mult EXT EXT EXT). Retraining, return to the three range values in the multiple schedule and re-exposure to extinction conditions was carried out for six of the subjects.

Discriminative stimuli for the various components consisted of various auditory and visual compounds consisting of white noise, a 500K tone, no white noise or tone (silence), a dim house light (upper left corner of front wall), a flashing white light to the left of the lever, and a steady white light to the right of the lever, counter balanced across subjects, stimuli and contingencies.

The rate of responding and post reinforcement pause (PRP) length during experimental and extinction conditions in each component was measured. Results indicated that with seven of eight subjects, manipulation of the range of the VR components had no systematic effect upon the PRP during experimental conditions or the overall rate of responding during experimental or extinction conditions. Any effects that were found were transitory or not replicated within or across subjects. High baseline rates of responding, short PRP lengths, failure to manipulate important variables and insensitivity of the multiple schedule are discussed as reasons for the ineffectiveness of the manipulation.

INTRODUCTION

Fixed ratio (FR) schedules of positive reinforcement were first described by Skinner (1938) and later, along with the variable ratio (VR), examined in detail by Ferster and Skinner (1957). Ferster and Skinner typically found that VR schedules produced relatively high rates of responding with little pausing and strong resistance to extinction (RTE). FR schedules were found to be bi-valued. That is, following reinforcement, a pause would occur which extended for several seconds and which was followed by a "run" of responses at a high steady rate until reinforcement. This pause and ratio run were also evident in extinction with the pauses gradually occupying a relatively larger proportion of the time.

Further research extended these findings to more complex situations such as second-order schedules (Findley and Brady, 1965; Kelleher, 1958, 1961) and matching to sample problems (Boren, 1973; Davidson and Osborne, 1974; Nevin, Cumming, and Berryman, 1963; Stubbs, 1968) as well as to various human populations (Holland, 1958; Hutchinson and Azrin, 1961; Long, Hammock, and Campbell, 1958; Schoenfeld, 1968; Weisberg and Fink, 1966).

Later studies also investigated important controlling variables of ratio schedules, and in particular FR schedules. For FR schedules it has been shown that the duration of the post reinforcement pause (PRP) is positively correlated with: the magnitude of

reinforcement (Lowe, Davey and Harzem, 1974), interreinforcement interval or the receiprocal of rate of reinforcement (Killeen, 1969b), ratio size (Crossman, 1971; Crossman, Heaps, Nunes, and Alferink, 1974; Felton and Lyon, 1966; Laursen, 1972; Powell, 1968) and, delay of reinforcement (Morgan, 1972). A variety of stimulus and response-requirement manipulations on complex schedules of reinforcement also have been shown to influence the length of the PRP (Barrett, 1975; Crossman and Silverman, 1973; Jwaideh, 1973; Keehn, 1965; Kelleher, Fry, and Cook, 1964).

Local rates on FR schedules are considered to be relatively stable throughout the ratio (Kelleher, 1958; Lowe, Davey and Harzem, 1974; Morgan, 1972) as well as at different ratio values (Laursen, 1972). However, some studies have shown changes in local rate across the ratio (Davison, 1969b) as well as at different ratio values (Felton and Lyon, 1966; Powell, 1968). It is difficult to draw any conclusions concerning local rate because of many procedural and measurement differences among these studies.

Generally then, the PRP has been shown to be sensitive to a variety of manipulations whereas the control of the local rate is much less clear.

VR schedules usually lack the PRP of the FR schedule and result in higher overall response rates and greater RTE (Boren, 1973; Ferster and Skinner, 1957; Schoenfeld, 1968). They also have been shown to produce more stable responding (Green, Sanders, and Squier, 1959) and better performance on a matching-to-sample task (Nevin, Cumming, and Berryman, 1963) than FR schedules with equal mean values.

Although Davidson and Osborne (1974) obtained poorer matching-to-sample performance on VR schedules, their data are less conclusive due to few observations of VR performance for each subject.

When animals are given a choice (e.g., a concurrent schedule) they typically will respond with a greater probability or rate to a stimulus which is correlated with a condition of greater variability. This "preference" has been shown for variability in reinforcement probability (Kendall, 1974), reinforcement magnitude (Essock and Reese, 1974), interval length on mixed or variable vs fixed intervals (Davison, 1969a; Frankel and Saal, 1976; Herrnstein, 1964b) and, ratio requirement on mixed vs fixed ratios (Fantino, 1967) or variable vs fixed ratios (Sherman and Thomas, 1968). (For a further discussion of previous ratio literature see Appendix 1.)

Since one of the defining features of a VR schedule is its variability from ratio to ratio it would seem that a VR with much variability may be "preferred" or would generate higher response rates than another VR with the same mean value but with less variability. Also, as the variability was reduced (i.e., less variation in ratio values) one might expect it to generate behavior like that of an FR schedule with the same mean value.

Using a three component multiple schedule, the present study was designed to investigate the response rate and PRP under three ranges of a mult VR30 VR30 VR30 schedule of positive reinforcement.

METHOD

Subjects

Eight experimentally naive, adult male, hooded rats served as subjects. All were individually caged and had free access to water in their home cages. Since subjects 1 through 4 had been housed in the laboratory for approximately three months prior to the research, their free-feeding body weights (mean=564.0 gm) were considerably greater than that of subjects 5 through 8 (mean=380.7 gm) who arrived about three weeks prior to the experiment. Thus, subjects 1 through 4 were maintained at 75% of their free-feeding body weights and subjects 5 through 8 were maintained at 80% of their free-feeding body weights. Food (Noyes 0.045 gm food pellets) was earned during daily sessions with supplemental feedings (Purina Lab Chow) given following sessions if necessary. On days when sessions were not conducted feeding occurred at approximately the same time of day.

Apparatus

The experimental chamber was a standard Grason-Stadler two lever chamber (Model No. 1111-P) with the right lever removed. Two stimulus lights were located 2.5 cm from either side and 11.4 cm above the floor. The third stimulus light was the house light which was located in the upper left hand corner of the end wall. A speaker was located 12.7 cm to the right of the centre and 2.5 cm above the floor. The entire chamber was enclosed in a sound attenuating chest equipped with a ventilating fan which also provided masking noise.

The tone was a constant 500-Hz. tone produced by a Philips PM5162 sweep generator while the white noise was produced by a Heath-Kit receiver. Cumulative records were obtained with four, Ralph Gerbrands cumulative recorders. A BRS/LVE Interact computer control system located in another room controlled the program and recorded responses and PRPs.

Multiple Schedule and Correlated Stimuli

A three component multiple schedule was used where all three components were either FR, VR, or extinction (EXT). During baseline conditions a mult FR30 FR30 FR30 was in effect while during extinction conditions the schedule was a mult EXT EXT EXT. In experimental conditions the subjects were exposed to a mult VR30 VR30 VR30, where the mean value of each VR component was equal but the range (rg) over which they varied was different. The specific values were VR30, rg11 (25-35; VR30, rg31 (15-45); VR30, rg51 (5-55). Following reinforcement, a particular ratio value was randomly selected from all the possible values within a given range.

The discriminative stimuli for the components of the multiple schedule consisted of various auditory and visual compounds composed of white noise, 500-Hz. tone, silence (no noise or tone), a dim house light, a flashing white light to the left of the lever, and a steady white light to the right of the lever. These were all

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Insert Table 1 about here

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counterbalanced across subjects, stimuli, and contingencies as shown in Table 1.

General Procedure

Sessions were conducted daily at approximately the same time with two to six subjects having simultaneous sessions depending on programming and apparatus requirements and limitations. Baseline and experimental sessions were 45 minutes long with each component of the multiple schedule being presented for a duration of five minutes and separated by a one-second "blackout" during which no discriminative stimuli were presented and responses had no programmed consequences. Presentations were programmed such that each component occurred once, but only once, during each third (15 minutes) of the session. Within each of these thirds, the order of presentation was random.

During extinction the discriminative stimuli changed every thirty seconds and were separated by a one-second "blackout" as above. Each stimulus compound was presented once, but only once, in each one and one-half minutes with the order of presentation during this period being random. Extinction sessions were continued for one hour or until no responses had occurred during the last five presentations of each of the discriminative stimuli.[1]

Table 2 shows the number of sessions in each experimental

Insert Table 2 about here

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phase for each subject. Experimental phases were changed for each subject when the graphical representation of response rate and PRP data for each component of the multiple schedule during the last six sessions appeared stable.[2] This criterion was applied for all

the experimental phases except extinction. All extinction phases lasted for a fixed length of six sessions.

Pretraining

Subjects were all taught to bar-press for food on a continuous reinforcement (CRF) schedule. The schedule was then progressively changed through short fixed ratios to an FR30. Pretraining sessions lasted for 45 minutes with discriminative stimuli changing as described above.

Baseline

During baseline all the subjects were exposed to a mult FR30 FR30 FR30 (where each FR30 may be also thought of as a VR30, rgl) with the discriminative stimuli changing as described above.

Experimental I

In this phase subjects were exposed to a mult VR30 VR30 VR30 with the ranges as described in Table 1.

Extinction I

As mentioned previously the first extinction session was preceded by a 15-minute "warm-up" under the experimental contingencies. Successive extinction sessions had no such warm-up and no responses were reinforced.

Retraining

When necessary following extinction, subjects were again taught to bar-press and then gradually moved through the smaller ratios until they were responding sufficiently well to be placed back on the experimental schedule. All but one subject recovered rates of responding high enough to be maintained by the experimental schedules after only a few minutes of CRF and low FRs.

Experimental II

This phase was identical to Experimental I.

Extinction II

This phase was identical to Extinction I.

Experimental III

This phase was identical to Experimental I and II.

Extinction III

This phase was identical to Extinction I and II.

RESULTS

Overall response rate data for baseline and experimental conditions are based upon responding during a 25-minute portion of the session, beginning five minutes after the start of the session and ending after 30 minutes of session time, thus reducing the variability due to warmup effects and satiation.

PRP data (i.e., the time elapsed between delivery of the reinforcer and the first response following reinforcement) from baseline and experimental conditions and response rate data in extinction conditions are based upon the entire session.[3] Data for both response rate and PRP are taken from the last six sessions of each phase of the experiment, while extinction conditions lasted only six sessions and data are from all six.

FR vs. VR Rates Comparison

For seven of eight subjects little or no consistent increase in response rate was noted when the schedules were changed from mult FR FR FR to mult VR VR VR. As shown in Figure 1, only subject 7 showed an increase in response rate for all ranges with repeated

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Insert Figure 1 about here

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presentations of the experimental conditions.

Range Comparisons Between VR Components

During experimental conditions no clear differences appeared in the rate data among any of the ranges for seven of the eight subjects. Any trends which did occur were transitory or failed to be

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Insert Figure 2 about here

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replicated in other experimental phases. Figure 2 shows the rate data for subject 6, which appears to be typical of these seven subjects.

Subject 2 did tend to show differential responding to the various ranges, with the highest rates occurring during the shortest range, lowest rates during the longest range, and intermediate rates during the medium range as shown in Figure 3. Although the short range also produced the highest rates during baseline conditions

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Insert Figure 3 about here

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the separation of the other two ranges during baseline was not so distinct as during the experimental conditions.

Extinction Comparison

Extinction data tended to show similar irregularity. Any trend which did occur lasted briefly or could not be replicated within or across subjects. This can be seen with subject 6 (see Figure 1), where the lowest rate occurred during presentations of stimuli correlated with the medium range value during Extinction I, but in Extinction III the lowest rates occurred during presentation of stimuli correlated with the shortest range.

PRP Comparison

PRP data as presented in Figure 4 revealed no consistent trends within or across subjects. Changing from baseline to

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Insert Figure 4 about here

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experimental phases resulted in the majority of subjects showing a

mixture of increases and decreases in PRP lengths across the experimental phases. Subject 2 showed a slight tendency toward shorter PRPs with the shortest range value. However, this tendency was also present during the baseline conditions.

Figure 5 shows that for subject 6, in two of the three experimental phases, there was a consistent inverse relationship

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Insert Figure 5 about here

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between length of range and length of PRP with the shortest PRPs occurring during the longest range. This effect was not noted however, during the first experimental phase or consistently in any other animal.

When the relative order of PRP lengths (i.e., shortest, medium, longest) is compared with the relative order of response rate (i.e., fastest, intermediate, slowest) no consistent relationship can be found either within or across subjects. Direct, inverse, and no relationship are all about equally probable. For a further description of the response rate and post reinforcement pause data for individual subjects, see Appendix 2.

DISCUSSION

With seven of eight subjects on a mult VR30 VR30 VR30 schedule of food reinforcement manipulation of the range of the VR schedules had no systematic effect upon the PRP during experimental conditions or upon the overall rate of responding during experimental or extinction conditions. When effects were found, they were typically transitory and were not replicated within or across subjects.

Response Rate Comparisons

Between experimental phases. All but one subject (subject 7) showed little or no difference in response rate during mult VR VR VR as compared with baseline rate under mult FR FR FR. Due to the high baseline rates (mean=176.2 responses per minute for all subjects except subject 7) increases in response rate may not have been possible. Some support for this view is evidenced by the rate data for subject 7 (see Figure 1). Subject 7 had the lowest baseline rate (mean=97.8 responses per minute) and was the only subject to show increases in response rate across successive applications of the experimental conditions.

Within experimental conditions. Since response rate measures are overall rates, changes in either local rate or PRP lengths could result in changes in rate. Because nothing inherent in the programmed contingencies would require systematic changes in variables previously found to be effective in controlling either of these, differences among the ranges should not be expected.

In studying fixed vs mixed ratios (MR) with equal mean values, Fantino (1967) found preferences for, and higher rates in, the initial variable-interval portion of a concurrent-chain schedule which led to the MR component. Sherman and Thomas (1968) found a similar preference (demonstrated as a switching response) for a VR over an MR with nine signalled ratio values. In neither study were rates of responding in the FR, MR or, VR directly compared. The present study used a multiple schedule to compare the various ranges and as such did not have a switching option or concurrently available alternatives. All components however, did favour maximum rates of responding. Because of these differences, a mult VR VR VR schedule may be insensitive to any range effects which may exist.

Sherman and Thomas also report that removing a one response requirement (i.e., the possibility of reinforcement following only one response) from the VR reduced the preference for the VR. This finding is consistent with conclusions about preferences for variable reinforcer duration (Essock and Reese, 1974), and of mixed or variable vs fixed interval schedules (Davison, 1969a; Herrnstein, 1964b). Despite low response requirements (from 5 to 15 responses) unique to the long range component, the present study failed to find such preferences. That ratio differences of this magnitude are discriminable has been demonstrated in pigeons using FRs (Hobson, 1975; Lydersen and Crossman, 1974). Differential responding for at least three consecutive sessions in all subjects that received extinction phases suggests that in this study the stimuli used were discriminable but that the contingencies were not effective in producing consistent rate differences during experimental phases.

Subject 2 did show differential response rates in the various components. However, a tendency for the highest rates to occur in component one, is also evident in the baseline conditions, during which all components are identical. Such preferences on multiple schedules have been noticed before in rats (Kieffer, 1965) and in pigeons (Lander, 1968).

Between and within extinction conditions. Since little or no differential responding occurred under experimental conditions the lack of consistent or replicable differential responding in extinction is not surprising. Subjects receiving more than one extinction phase showed decreased rates of responding in successive extinction conditions for all components with virtually no exceptions. However, when subjects 6 and 7 received Extinction III response rates for each subject were higher in all three components than in Extinction II and in two of three components, higher than in Extinction I. This reversal can not be accounted for on the basis of response or reinforcement rate differences in the preceding experimental phase since, in the case of subject 6, the response rate in Experimental III was less than or equal to the rate in Experimentals I and II. In addition, the number of experimental sessions preceding successive extinction phases was approximately equal for subject 7 (22, 23, and 28 sessions respectively) while for subject 6, Extinction II was preceded by the largest number of sessions. Thus, the cause of the reversal in trend for subjects 6 and 7 is difficult to explain, especially since no other subjects experienced the third experimental and extinction phases.

PRP Comparisons

Between experimental phases. PRP data showed no systematic changes in PRP lengths across experimental conditions for any subject. Although most studies report longer PRP lengths for subjects on FR schedules than on VR schedules (Boren, 1973; Fantino, 1967; Ferster and Skinner, 1957) the relatively short PRP lengths during baseline may have prevented the possibility of shorter pauses. It should be noted that subject 1 had relatively shorter PRP values than other subjects. Direct observation of this subject indicated that he often "overshot" the ratio by one response. Thus the PRP lengths were considerably reduced.

Within experimental conditions. As with response rate, no established powerful variables were manipulated and as such, differences among the PRP lengths due to different ranges should not be expected. All subjects typically demonstrated this non-differential pausing.

It is of interest to note that in the case of subject 2, even though large differences in response rates were observed among the three components in Experimental III, there were no consistently large differences among the PRP lengths for the various components. This suggests that the differential rates observed for subject 2 could not be accounted for solely on the basis of extended PRPs. Inspection of cumulative records for this subject also revealed that response rate reduction was not due to multiple pausing as observed by Felton and Lyon (1966) in their investigation of PRPs and local rates on FR schedules. It would then seem that a change in the local response rates was likely.

One further general point should be mentioned. The high rates of reinforcement produced what appeared to be the satiation in the subjects. Overall response rates declined considerably (frequently from about 200 to 150 responses per minute) across the session. Because components were presented randomly within the thirds of the session, the overall response rates for the sessions varied extensively from session to session. This uncontrolled variation made it difficult to detect any effects the various ranges may have had. For similar reasons session to session variation would be expected in the PRP data since the PRP had been shown to be a function of rate of reinforcement (e.g., Killeen, 1969) which decreased across the sessions. Unfortunately, such intrasession variation was not measured. For a further discussion of the results, see Appendix 3.

In summary, using a three component mult VR30 VR30 VR30 schedule, manipulation of the range of the VR components failed to have any consistent effects upon the overall rate of responding in experimental or extinction conditions, or the length of a PRP. In part, failure to manipulate any established, powerful variables either directly or indirectly might explain these results. In addition, near maximum rates of responding and near minimum PRP values could have contributed to the ineffectiveness of the variable. Non-overlapping range values and concurrent schedules may prove to be a more sensitive measure.