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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

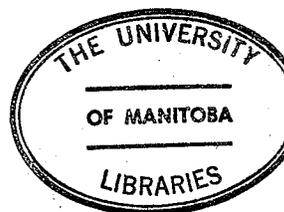
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"EFFECTS OF THE MANIPULATION OF THE RANGE
OF THE VARIABLE-RATIO COMPONENTS
OF A MULTIPLE SCHEDULE UPON
RESPONSE RATE AND POST-REINFORCEMENT"

by

WILLIAM B. LEONHART

A dissertation submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
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MASTER OF ARTS

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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 reciprocal 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-Statler 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

Insert Table 1 about here

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

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

 Insert Figure 1 about here

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

 Insert Figure 2 about here

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

Insert Figure 3 about here

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

Insert Figure 4 about here

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

Insert Figure 5 about here

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.

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FOOTNOTES

1. In order to obtain transition data from experimental to extinction conditions in the form of cumulative records, the first extinction session following each of the experimental conditions was preceded by 15 minutes of the experimental procedure. This 15-minute warmup did not enter into any of the data calculations. Thus, the first session of each extinction phase could last a maximum of 75 minutes.
2. Although judged by visual inspection, a criterion of stability was used to assist in evaluating the response rate data. The standard deviation of response rates in each component over the last six sessions for individual subjects was calculated. If all values were less than or equal to 10, responding was judged to be stable. Values exceeding 10 were judged to be stable if the source of variability could be attributed to one or two deviant data points for which some explanation could be found (e.g., stimulus light out, plugged feeder, disturbing noises, etc.).

3. Since the programming equipment recorded only the cumulative PRP length and number of reinforcers for each component for each session, the mean PRP length for any given component had to be calculated over the entire session. Response rates during extinction sessions also were calculated for each component for the entire session since the lengths of the extinction sessions could vary from 15 to 60 minutes.

TABLE 1

Counterbalancing of range values during
 experimental conditions and correlated
 stimulus compounds for all eight subjects.

Subjects	Stimulus	Stimulus Compounds	Range
1 and 5	1	white noise & houselight	rg. = 11 (25-35)
	2	silence & right light	rg. = 31 (15-45)
	3	tone & left light ^a	rg. = 51 (5-55)
2 and 3	1	tone & right light	rg. = 11 (25-35)
	2	white noise & left light	rg. = 31 (15-45)
	3	silence & houselight	rg. = 51 (5-55)
4 and 6 ^b	1	silence & left light	rg. = 11 (25-35)
	2	tone & houselight	rg. = 31 (15-45)
	3	white noise & right light	rg. = 51 (5-55)

a Presentation of the left light occurred as a .50 sec. on,
 .25 sec. off cycle throughout the component.

b During the third experimental condition for subject 6, the
 stimulus compounds were changed such that they were identi-
 cal to those of subjects 2 and 3.

TABLE 2

Summary of the experimental phases and the number of sessions in each phase for each subject.

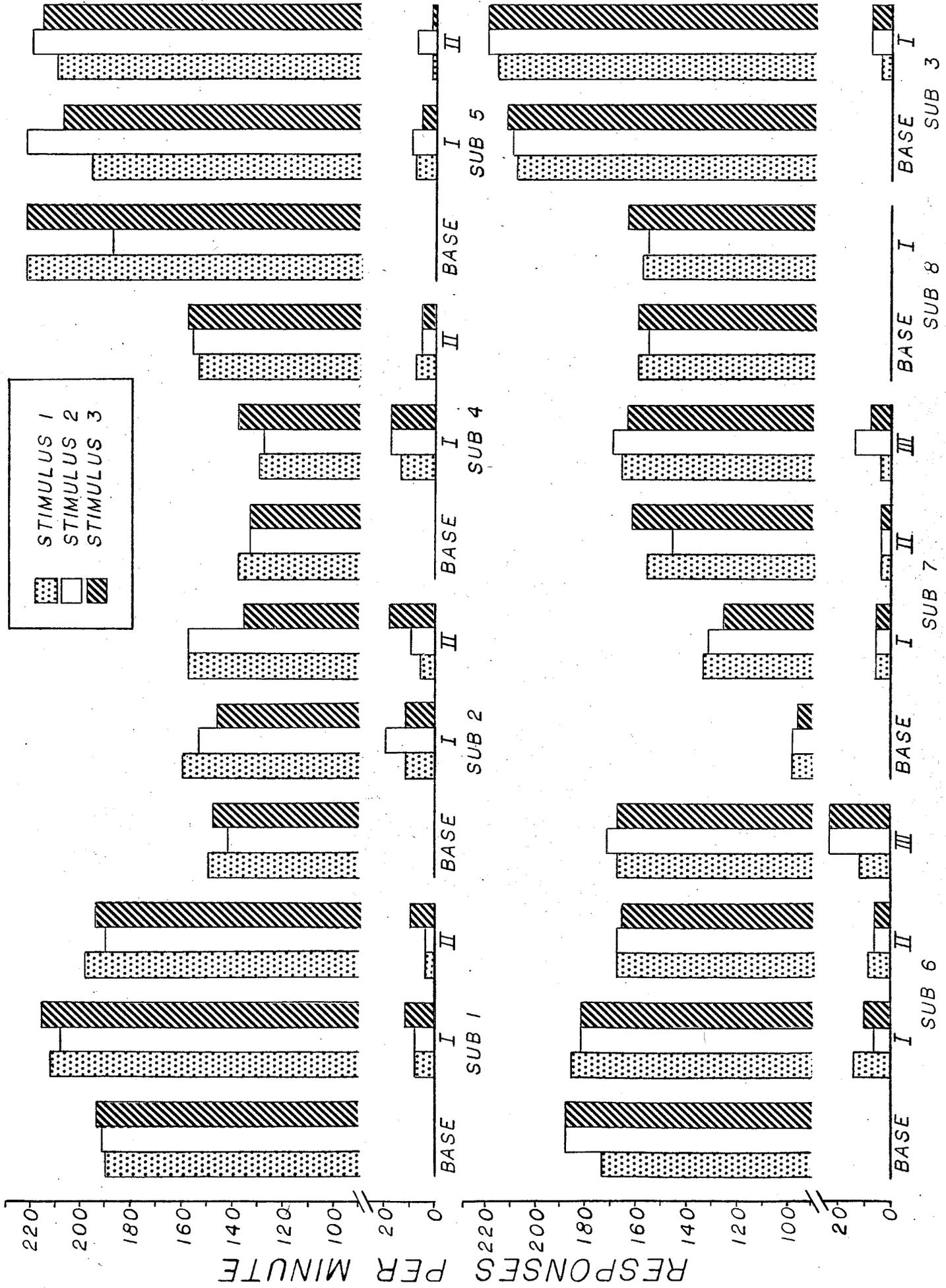
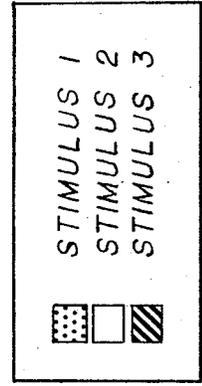
Experimental phase	Subjects							
	1	2	3	4	5	6	7	8
Baseline								
Mult FR FR FR	28	33	23	45	27	8	6	39
Experimental I								
Mult VR VR VR	53	15	73 ^a	23	28	13	14	24
Extinction I								
Mult EXT EXT EXT	6	6	6	6	6	6	6	-
Experimental II								
Mult VR VR VR	13 ^a	17	-	27 ^a	28 ^a	29	23	-
Extinction II								
Mult EXT EXT EXT	6	6	-	6	6	6	6	-
Experimental III								
Mult VR VR VR	-	-	-	-	-	24 ^a	29 ^a	-
Extinction III								
Mult EXT EXT EXT	-	-	-	-	-	6	6	-

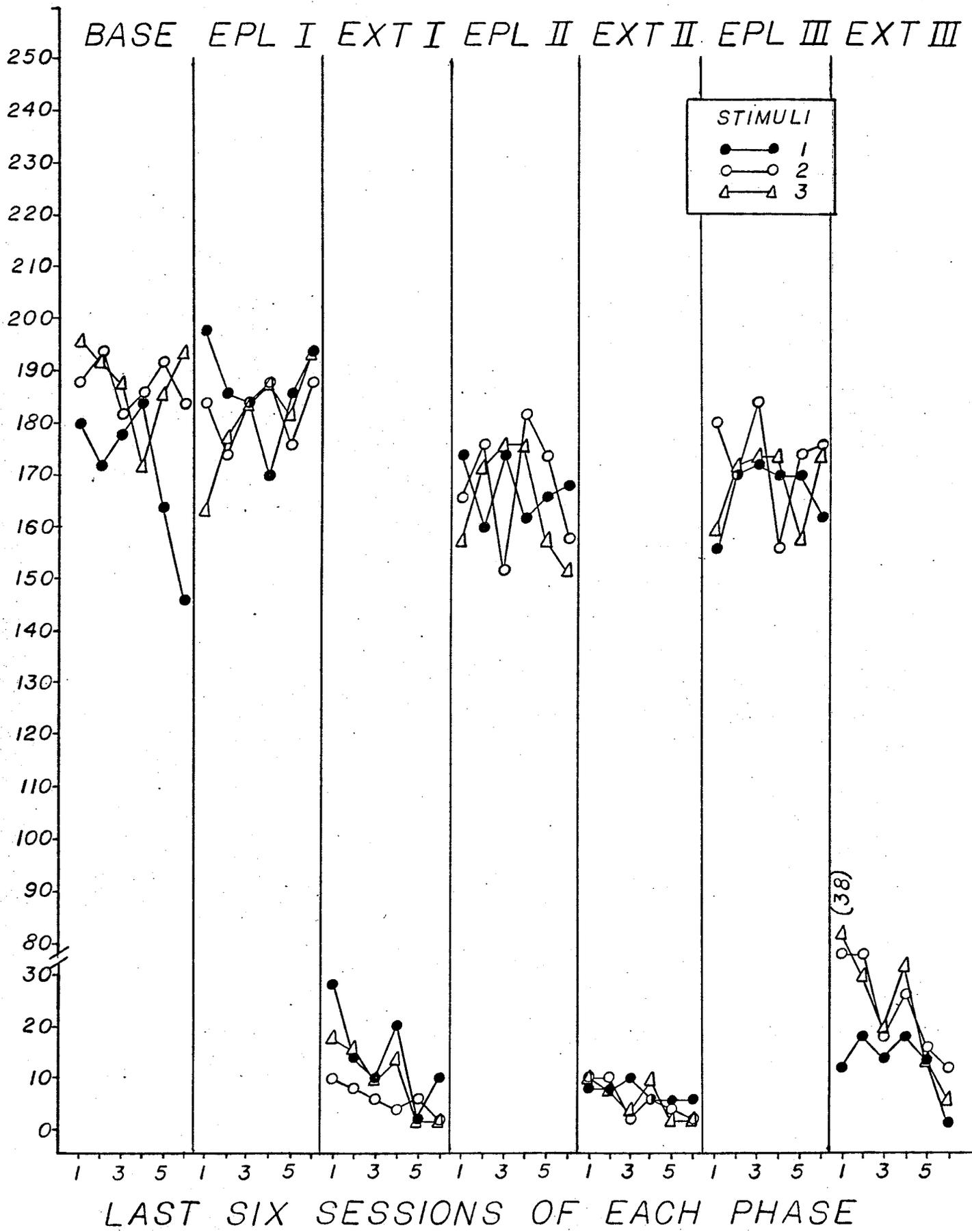
a Experimental phases were changed regardless of stability because of time or equipment limitations.

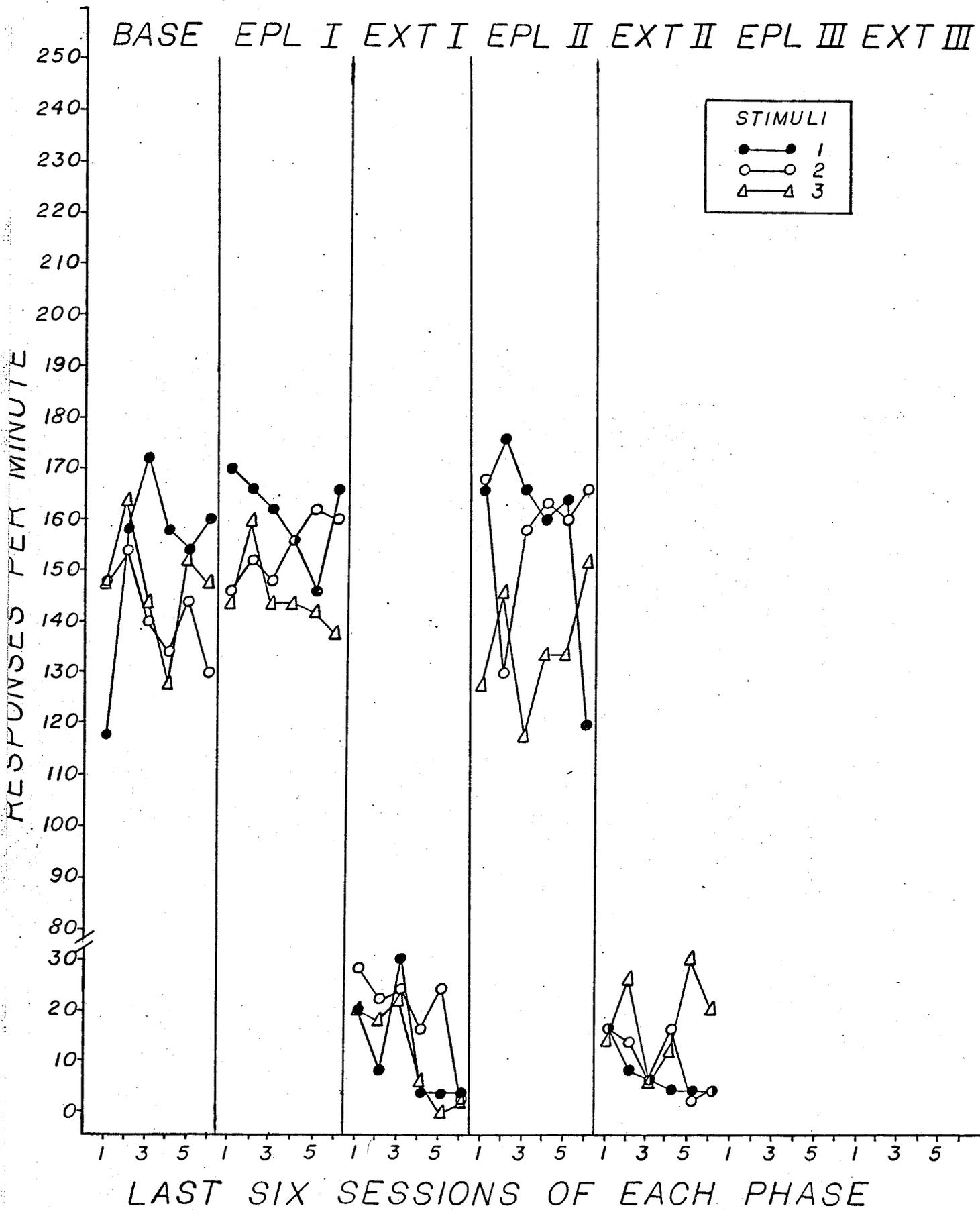
FIGURE CAPTIONS

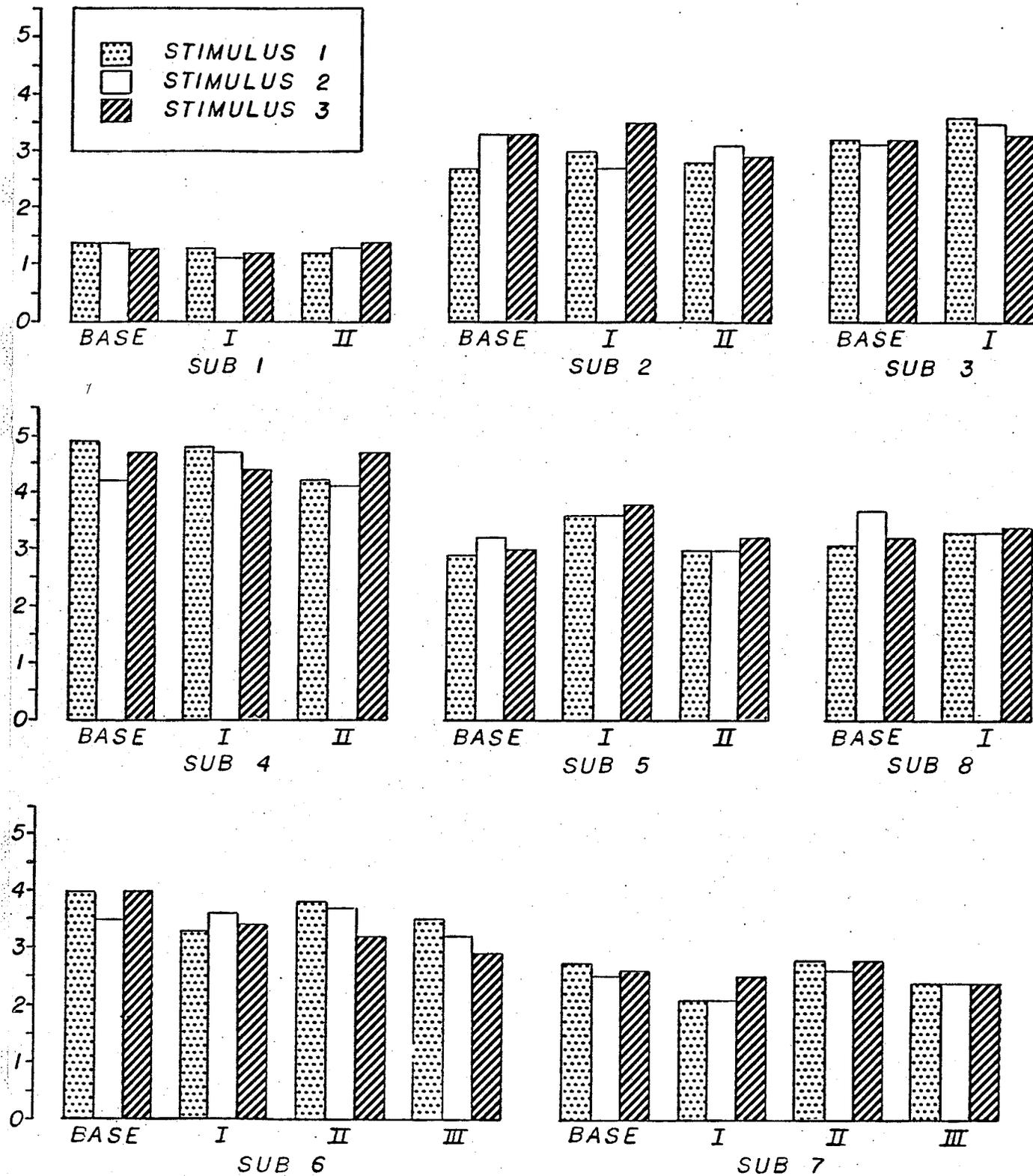
- Fig. 1. Mean overall response rates for all subjects for the last six sessions of baseline (BASE) and each experimental and extinction conditions (I, II, and III) during presentations of each of the three stimuli. Stimuli 1, 2, and 3 were the stimulus compounds correlated with ranges 11, 31, and 51 respectively as described in Table 1. Note the broken ordinate and the lower separated portions which indicate performance in extinction condition following the above experimental condition.
- Fig. 2. Response rate data for subject 6 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1.
- Fig. 3. Response-rate data for subject 2 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) conditions. Stimuli 1, 2, and 3 are as described in Table 1.
- Fig. 4. Mean PRP lengths for all subjects for the last six sessions of baseline (BASE) and each of the experimental conditions (i.e., I, II, and III). Stimuli 1, 2, and 3 are as described in Table 1.

Fig. 5. Mean PRP length for subjects 3, 6, 7, and 8 for the last six sessions of baseline (BASE) and each experimental (EPL) condition. Stimuli 1, 2, and 3 are as described in Table 1.



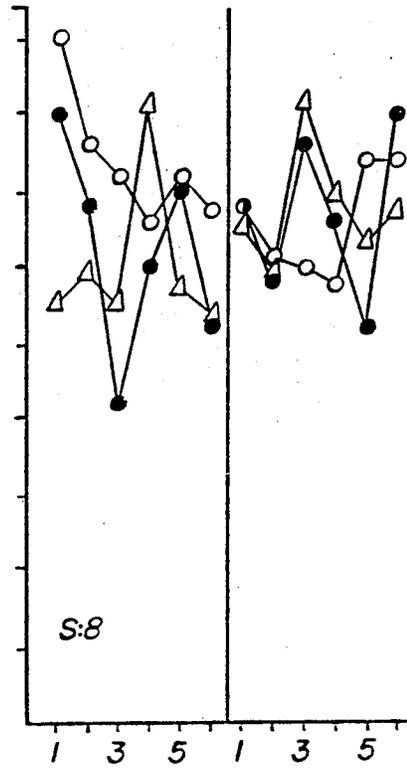
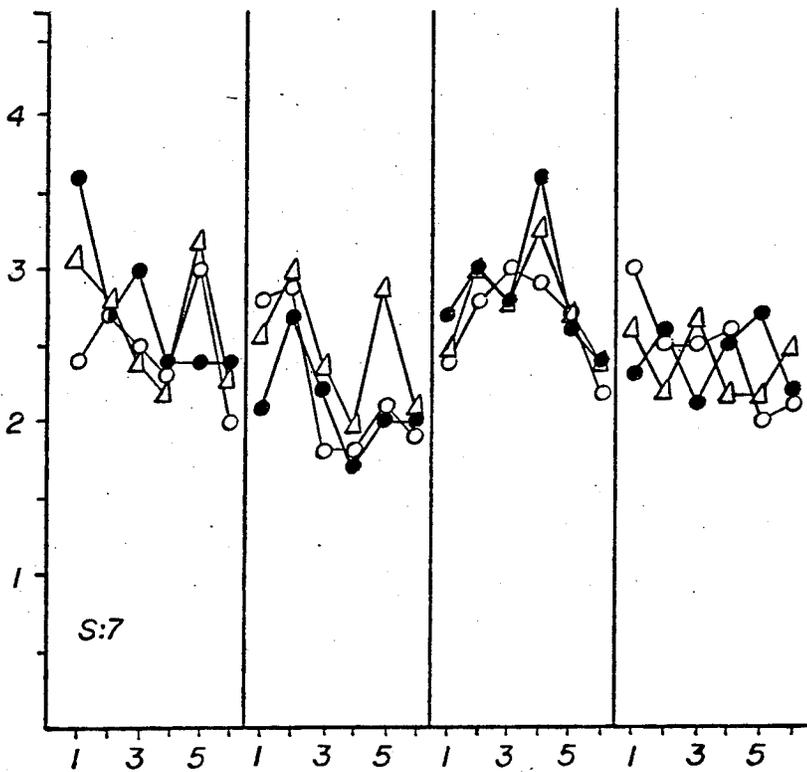
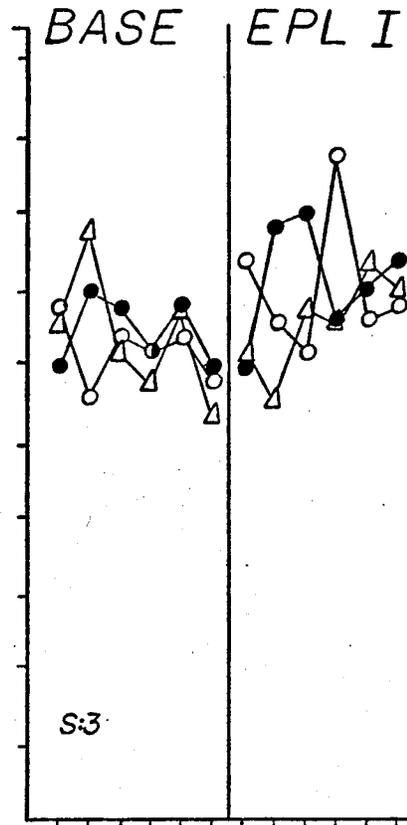
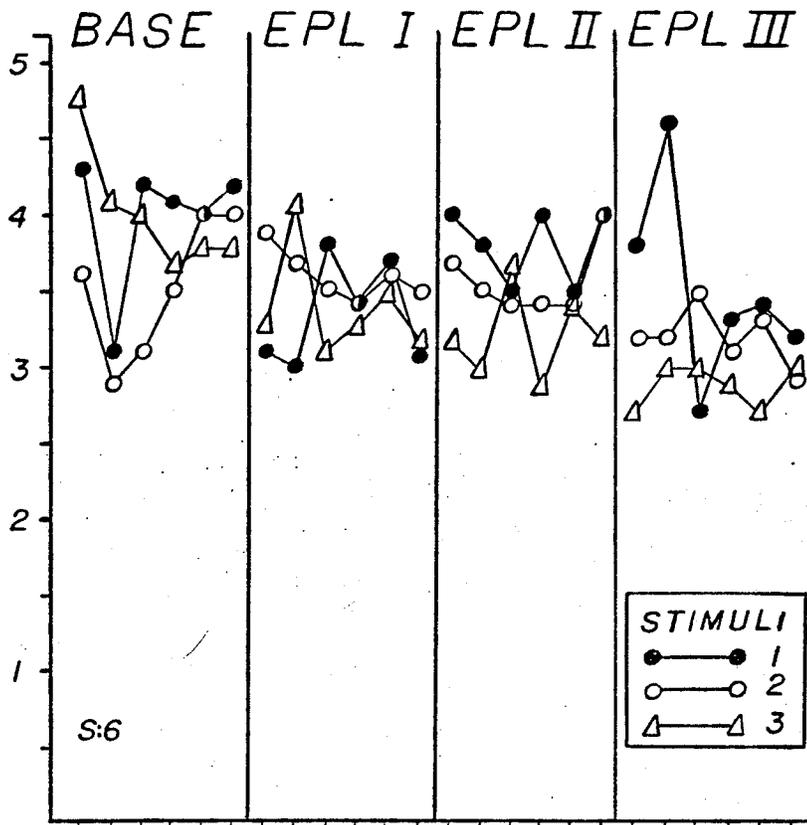






EXPERIMENTAL PHASES

SECONDS



LAST SIX SESSIONS OF EACH PHASE

APPENDIX I

EXTENDED LITERATURE REVIEW

The characteristics of the FR and VR were described in some detail by Ferster and Skinner (1957). They reported that the FR schedule produced a response rate pattern. That was bi-valued. It typically was composed of a "run" of responses which was found to be steady, contained few pauses, and relatively insensitive to a variety of experimental manipulations (e.g., ratio size).

The second component of the FR pattern was the PRP which typically followed immediately after reinforcement. Ferster and Skinner suggested that the pause was not due to such things as fatigue, satiation, or time spent eating but rather they suggested that the period of time immediately following reinforcement was a period during which the probability of a response was also low. Unlike the ratio run, the PRP length was shown to be positively related to ratio size.

This bi-valued pattern was also displayed in extinction. Frequently, bursts of responding would occur which resembled the ratio runs. In addition pauses typically occurred after such bursts. As extinction progressed periods of no responding gradually came to occupy a relatively larger proportion of the time.

Like the FR, the VR is also characterized by high rates of responding although the prolonged pause following reinforcement is typically not found (e.g., Ferster and Skinner, 1957). Since a VR may schedule a reinforcer to be delivered following only one response the probability of reinforcement (when calculated over many reinforcements) immediately following reinforcement is greater than zero. Thus, responding is typically initiated more quickly on a VR than on an FR which results in higher overall rates on VRs than on FRs with equivalent mean values (particularly at higher ratio values).

In addition, Ferster and Skinner found greater RTE for VRs than for FRs of equivalent mean values. Although the VR schedule produced occasional bursts of responding in extinction as well as some extended pausing, the pattern was not so distinct as that which followed FR schedules. Also, extinction following VR schedules showed somewhat of a gradual decline in response rate.

Further research extended these early findings of Ferster and Skinner to more complex situation. Kelleher (1958) used a second-order schedule with chimpanzees using poker chips as conditioned reinforcers. Completion of a fixed ratio resulted in a poker chip. Exchanging the poker chips for food required a specified number of chips. Thus, a second order FR(FR) was established. Kelleher reported characteristic FR patterns of behavior (i.e., ratio runs and PRP) with the animals. Using a similar design Kelleher (1961) also reported FR patterns of extinction behavior.

Using a second-order multiple schedule, Boren (1973) reported FR and VR schedule characteristics with pigeons on a matching to sample task. He compared performance on a variety of ratio values ranging from 1 to 64 with a mult FR(FI) VR(FI) schedule and found little difference in performance at ratios of 1 to 4. At higher values the FR(FI) component generated PRPs and lower overall response rates than did the VR(FI) component using the same mean ratio and interval values.

Characteristic ratio behavior has also been found for matching to sample tasks in pigeons by Nevin (1963) and by Stubbs (1968). Both studies reported better performance on VR schedules than on FRs. Using a match to sample task with children Davidson and Osborne (1974) report slightly better accuracy on FRs than on VRs. The proportion of errors tended to be greatest near the beginning of the ratio during FR schedules but was unrelated to position during VR schedules. Although this study departs slightly from other findings, the differences in accuracy were small (i.e., typically less than 10 percent), there were few observations of VR performance, and for two of five subjects receiving VR schedules accuracy was better during the VR schedule than during the FR schedule.

Studies have also investigated some of the important controlling variables of ratio schedules, and in particular FR schedules. It has been shown that the duration of a PRP is directly related to the size of the ratio (Crossman, Heaps, Nunes, and Alferink, 1974; Felton and Lyon, 1966; Laursen, 1972; Powell, 1968). Crossman et al point out that changing the ratio value of an FR schedule typically

involves a simultaneous change in the time to complete the ratio (working time) and in the time between successive reinforcements (interreinforcement interval). By using a mult FRx FR2 + time out (TO) Crossman et al were able to manipulate the size of the ratio in one component (FRx) while in the other (FR2 + TO) it was possible to equate either the working time or the interreinforcement interval (IRI) by changing the length of the TO. After completing the FRx component, the pigeon was reinforced and the key light changed. Under these conditions the chamber would darken following one response and would remain darkened for a period of time which equalled the median working time in the FRx component from the previous day. The chamber and key light would again come on and one response would produce a reinforcer and a change in the colour of the key light which was correlated with the FRx component.

In a similar manner the TO length could be adjusted to control for equivalent IRI lengths in both components. Under both conditions the ratio size was shown to be directly related to the size of the PRP.

Lowe, Davey, and Harzem (1974) used varying milk concentrations to demonstrate a positive relationship between length of the PRP and the magnitude of reinforcement with rates on an FR30 schedule. Using a yoked control design, Killeen (1969b) found an inverse relationship between the length of the PRP and rate of reinforcement. A similar positive relationship was found between the length of the PRP and the delay of reinforcement following the completion of an FR9 schedule (Morgan, 1972).

In addition, PRPs have been manipulated more directly (Kelleher, Fry, and Cook, 1964). In one experiment Kelleher et al made reinforcement contingent upon the completion of a fixed ratio following a PRP of a specified length. This resulted in the mean PRP length approximating the specified value.

Keehn (1965) found longer pausing prior to the longest FR in a mixed schedule and prior to a chain schedule containing a larger response requirement than a second chain schedule in a mix (chain chain) schedule.

Finally, Jwaideh (1973) found longer pauses following completion of the FR components of a mixed schedule than following completion of identical FR components on a tandem schedule. She also found that the PRP increased with larger ratio requirements and the addition of more ratios. In addition, for the mixed schedule, the PRP decreased across the ratios. Interestingly, when the stimuli correlated with the FR components of the mixed schedule were reversed the pattern of PRP lengths reversed as well (i.e., the shortest PRP preceded the first FR). These effects were temporary and original pattern was re-established. However, when the stimuli correlated with the first and last FR were the same consistent, short pauses occurred prior to the first FR.

Although the PRP has been shown to be sensitive to a variety of manipulations, the local rate on FR schedules is 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). Despite increased overall response rate on a second order FR(FR) schedule Kelleher reported relatively stable

inter-response times throughout the schedule. Lowe et al found no systematic changes in local rates as a function of milk concentration while Morgan found only small and inconsistent changes in local rate with changes in delay of reinforcement. Manipulating gradual and sudden changes in ratio size with monkeys, Laursen found the mean IRT to be insensitive to changes.

However, Davison (1969b) reports a decrease in IRTs over the first few responses on a low FR schedule as well as a similar decrease for FRs in a second order schedule. Also, Powell (1968) reported slight increases in local rates at higher FR values. Conversely, Felton and Lyon (1966) reported slightly lower local rates at higher FR values although they point out that this may be due to multiple pausing during the ratio rather than longer IRTs in general.

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 distinct PRP and typically result in greater RTE (Boren, 1973; Ferster and Skinner, 1957; Schoenfeld, 1968). In addition, VR schedules tend to produce more stable overall responding at higher values than FR schedules of equal mean values. Green, Sanders, and Squier noted that VRs tend to become more stable with increased mean ratio values whereas FRs tend to become less stable. This reduction in stability can be seen in the data of Laursen (1972) where increased ratios on FR schedules increased the variability of the length of the PRP.

However, Sidley and Schoenfeld (1964) report that with random ratio schedules (i.e., a schedule in which the probability of reinforcement for any given response is equal to some specified value) there tends to be an increase in response rate variability at lower probabilities (a condition which approximates higher mean values on VR schedules).

Preference for schedule variability has been demonstrated with respect to a number of variables. Herrnstein (1964b) used a concurrent-chain schedule to present a choice to pigeons. Responding on the left key darkened the other and made available either a fixed interval (FI) or a variable interval (VI) schedule of equal mean value. Responding on the interval schedule was reinforced with food and the two keys again were lighted. If the pigeon were to respond on the right key, the left key would darken and responding on the right key would be reinforced on an FI schedule only, with a mean value equal to that on the left key. Pigeons developed a preference for the key which occasionally produced a VI schedule.

In a similar study Davison (1969a) found preferences for a key which produced a mixed interval (MI) schedule (i.e., either of two FI schedules) as opposed to a key which produced a fixed interval schedule with an equal mean value.

Kendall (1974) found that when pigeons were presented with two darkened keys they preferred to peck the key which would produce a colour which was correlated a delay followed by either food or T0. The alternative was a key which would produce a colour which was correlated with the same delay followed by food every time. This preference was maintained when the response requirement for lighting

the key was changed from one peck to a VI 20-sec. In addition, increasing the delay period increased the preference, while reducing the probability of reinforcement on the less preferred key reduced the preference for the preferred key.

Fantino (1967) also used a concurrent chain schedule to study preference between an MR and FR. Higher relative rates of responding were found on the initial VI link leading to the MR terminal link. The MR was composed of two FRs with their mean value equal to the ratio requirement of the FR alternative (i.e., FR50).

Moreover as the difference between the two FRs comprising the MR increased (e.g., from FR25 and FR75 to FR10 and FR90 to FR1 and FR99) the relative rate of responding on the preceding VI link increased dramatically. Using the values of FR1 and FR99 to make up the MR, the relative rate of responding for five pigeons averaged just over .70.

Sherman and Thomas (1968) studied pigeons on a Findley concurrent schedule (Findley, 1958, 1962). A series of nine FRs with correlated stimuli (key colour) were arranged as one component of the concurrent schedule while a VR schedule composed of the same nine FRs but with no discriminative stimuli composed the other. The pigeons were presented with one of the nine stimuli correlated with one of the FRs. They could complete the ratio or peck a second key to switch the schedule to the VR schedule. Following reinforcement on either an FR or VR, a stimulus correlated with one of the nine FRs would again be presented.

Pigeons were found to prefer the VR schedule even when the switching response was increased to the point where the total switching and VR responses exceeded the necessary FR response requirement. Eliminating the possibility of a single response requirement from the VR component reduced this preference as did introducing a delay following a switch if the response requirement on the VR was scheduled to be one.

Another dimension of variability was investigated by Essock and Reese (1974). They varied the duration of access to a grain hopper with pigeons. In one experiment a mult FR30 FR30 ended in a fixed period of grain access (FS^R) for one component while the other ended in a variable period of grain access (VS^R). The FS^R duration was five seconds and the VS^R used various combinations of 2, 3, 4, 6, 7, and 8 seconds to average 5 seconds. All birds showed higher overall rates of responding on the FR component ending in VS^R .

When the multiple schedule was changed to a conc (FR30, VS^R5) (FR30, FS^R5) a preference for the key light which was correlated with the (FR30, VS^R5) component was developed. For one subject, the average variable duration was gradually reduced to half the fixed duration while the preference was maintained.

Briefly then, it is possible to conclude that FR schedules tend to be bi-valued, consisting of a ratio run at a fairly high steady rate and a PRP extending for several seconds. VR schedules tend to produce higher steady rates and are more resistant to extinction. While the PRP has been extensively studied and major controlling variables identified, investigations concerning the ratio run are somewhat ambiguous.

In addition, there is good evidence to suggest that variability along several dimensions is preferred when choices are made available on concurrent schedules. Also, higher rates of responding can be maintained when conditions of greater relative variability are made contingent upon responding in one component of a concurrent or multiple schedule.

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APPENDIX 2

EXTENDED PRESENTATION OF RESULTS

Schedule Effects

FR vs VR. Seven of eight showed virtually no systematic increase in response rate when switched from mult FR FR FR to mult VR VR VR. For one subject (subject 7) the mean response rate for all components increases with each application of the experimental (EPL) conditions as shown in Figure 1 (see METHOD section). It is important to note that for this subject the mean response rate averaged across components during baseline conditions (BASE) was 97.8 responses per minute as compared with a mean of 176.2 responses per minute for all other subjects.

Subject 3 shows a slight increase from a mean BASE rate of 209.7 responses per minute to an EPL I rate of 218.7 responses per minute. Such increases have been followed however by subsequent decreases as with subjects 1 and 2. Subject 4 also shows some tendency towards an increasing response rate in EPL II, however, the response rate averaged across components was less for EPL I than for BASE.

By calculating the standard deviation for each component in BASE and EPL conditions measures of variability of the response rates were obtained for each subject. Averaging across components and EPLs resulted in two measures of variability for each subject.

In four of eight subjects the mean standard deviation for EPL conditions was less than for BASE.

It should be noted that occasionally a particularly deviant data point occurred, as with subject 5 in Figure 1 (EPL II, S¹, session 5) and with subject 1 in Figure 2 (BASE, S³, session 4 and EPL II, S¹, session 3). These data were typically the result of

Insert Figures 1 and 2 about here

equipment malfunctions (e.g., jammed feeders, burn out stimulus lights, etc.) or prolonged pauses in responding which usually occurred following reinforcement but after one or two bar presses. In any event these data were retained when variability calculations were done but seemed not to distort or mask any general data trends (e.g., greater variability in EPL conditions for subject 5).

As with response rate data, PRPs averaged across components did not show any systematic changes when EPL conditions were introduced. Figure 4 (see METHOD section) shows that for subjects 3 and 8 a slight increase can be noted in PRP length but only one observation under EPL condition is available for each. Also, such an increase is shown for subject 5, however, in EPL II the PRP length decreases to about BASE level.

Subject 4 did tend to decrease across EPLs, however, the decrease from BASE to EPL I is only 1/100 second when averaged across components. Subject 6 also shows a slight decrease across EPLs, with all EPLs being less than BASE but with EPL II showing the largest mean value.

It is interesting to note that for subject 7, although the mean response rate increases systematically from BASE and across EPLs, there is no corresponding orderly change of any kind in the PRP data. Mean PRP length decreases and increases independently of overall response rate. This suggests that response rate changes for subject 7 are not due to decreasing PRPs.

Extinction conditions. All of the six subjects that received multiple exposure to extinction conditions (EXT) responded more slowly in EXT II than in EXT I when response rates are averaged across components. However, for the two subjects (6 and 7) presented with EXT III, both showed mean rates greater than either EXT I or II.

Range Effects

Rate during VR components. For all subjects no systematic differences among the components was apparent. Since components 1 and 3 were correlated with the extreme range values (i.e., rg 11 and rg 51 respectively) differences between component 1 (S^1) and component 3 (S^3) were analyzed while ignoring component 2.

It was found that response rate in S^1 was about equally likely to be greater than or less than in S^3 . This was true in BASE and in EPLs. Only four subjects showed consistency with respect to higher response rates in S^1 than in S^3 (subjects 2 and 7) or in S^3 than S^1 (subjects 1 and 3 from BASE to EPL I. The other four subjects changed the relative order. Of the six subjects that received EPL II, four (2, 4, 5, and 6) maintained a consistent relationship between rates in S^1 and S^3 , however S^1 was again a likely to show higher rates as lower rates. Neither of the two subjects (6 or 7) receiving EPL III

maintained a consistent relationship across all three EPLs, although subject 6 came close since the mean response rates in S^1 and S^3 were equal when rounded off to an even whole number. Without rounding off the mean response rates show a difference of only .1 responses per minute with S^3 greater than S^1 .

PRP during VR components. As with the response rate data, inspection of Figure 4 reveals no consistent, systematic differences among the components with respect to PRP length. When PRP length is compared for components 1 and 3, again ignoring component 2, analysis of BASE conditions reveals that the PRP in S^1 is equally often greater than or less than in S^3 . In EPL I five subjects (2, 5, 6, 7 and 8) show shorter PRPs in S^1 than in S^3 . In EPL II four of six subjects (1, 2, 4, and 5) show a similar trend with one subject (7) showing equal PRPs in S^1 and S^3 . Finally, in EPL III, for the two subjects receiving this condition, subject 7 shows equal PRPs in S^1 and S^3 while subject 6 shows longer PRPs in S^1 than in S^3 .

When consistency across experimental phases is investigated the data show that from BASE to EPL I five subjects (1, 2, 4, 5, and 8) show consistency for either longer PRPs in S^1 than in S^3 (1 and 4) or shorter PRPs in S^1 than in S^3 (2, 5, and 8). Only two subjects show consistency across BASE, EPL I and EPL II (2 and 5) and only two more show consistency across any two EPLs (6 and 7).

Variability of response rate during VR components. Table 1 shows the standard deviations of response rates for each component, for each subject across experimental phases and from which the rank order of variability among the components was compared. Given three components, six possible orders of ranks could occur. Thus, if

Insert Table 1 about here

assigned at random a given rank order would occur in 16.7% of the time (i.e., one out of every six times).

In BASE only one subject showed systematic changes in variability across components in the fashion of $S^1 > S^2 > S^3$ (subject 3) and one subject (8) showed the reverse order of $S^3 > S^2 > S^1$. The other six subjects all showed various rank orders. In EPL I two subjects (1 and 7) showed rank orders in variability of the first kind described above and one (8) showed the second kind. Of the six subjects exposed to EPL II three (1, 2, and 5) showed rank orders of the first kind and one subject (7) of the second. In EPL III (two subjects) only subject 6 showed a rank order of the first kind (i.e., $S^1 > S^2 > S^3$). Over all observations of subjects in EPL conditions (i.e., sixteen), six observations (i.e., 37.5%) of systematic changes in variability across components of the fashion $S^1 > S^2 > S^3$ occurred.

When standard deviation scores for components 1 and 3 were compared, again ignoring component 2, S^1 was found to be greater than S^3 during BASE for four subjects (2, 3, 5, and 6). During EPL I six subjects (1, 2, 3, 4, 5, and 7) showed this tendency for $S^1 > S^3$ while in EPL II four (1, 2, 4, and 5) of six and in EPL III two (6 and 7) of two subjects showed greater variability in S^1 than in S^3 . Again, looking at all observations of subjects in EPL conditions (i.e., sixteen) revealed twelve (i.e., 75.0%) observations of greater variability in S^1 than in S^3 compared with four of eight (i.e., 50%) such observations during BASE.

The data in Table 1 also show that four subjects (2, 3, 5, and 8) retained the same relationship between S^1 and S^3 with respect to variability from BASE to EPL I and that two subjects (2 and 5) maintained this relationship into EPL II, although subjects 3 and 8 never received EPL II. Of these four subjects, only subject 8 displayed a tendency for less variability in S^1 than in S^3 . In addition, the tendency for greater variability in S^1 than in S^3 was found to be consistent from EPL I to EPL II in four (1, 2, 4, and 5) of six subjects while the reverse tendency was found only in subject 6. No subjects were found consistent across these EPLs.

Rate during extinction components. The response rate data show no consistent trends among the components for any subject with the possible exception of subject 1. Subject 1 does tend to show higher rates of responding in component 3 in both EXT I and II as well as equal rates in components 1 and 2. For all subjects response rates in extinction do not seem related to response rates in the immediately preceding experimental conditions. Subject 2, who showed the greatest differences between rates in S^1 and in S^3 showed no systematic differences across EPLs.

Since the majority of responses in extinction were made during the first few minutes, response rates were calculated for each component for the first two presentations of the correlated stimuli and for the duration of the session. Such analysis also revealed no systematic trends among the components. A similar result occurred when the data were analyzed in terms of percentage of presentations in which one or more responses occurred, for each stimulus correlated with the experimental conditions.

Individual response rate data for subjects 3, 4, 7, and 8 may be seen in Figures 3, 4, 5, and 6 respectively.

Insert Figures 3, 4, 5, and 6 about here

Also , individual PRP data for subjects 1, 2, 4, and 5 may be seen in Figure 7.

Insert Figure 7 about here

TABLE 1

Standard deviation scores for each component of the multiple schedule as calculated from the last six sessions of baseline (BASE) and experimental (EPL) conditions.

Condition Stimulus ^a	Subject								
	1	2	3	4	5	6	7	8	
BASE	s ¹	10.2	18.4	11.8	5.5	14.2	14.0	5.7	8.9
	s ²	7.1	9.3	6.4	15.3	6.1	4.6	5.7	9.1
	s ³	36.8	11.5	5.7	8.4	13.7	8.6	8.5	9.7
MEAN BASE	all	18.0	13.1	8.0	9.7	11.3	9.1	6.6	9.2
EPL I	s ¹	7.7	8.9	12.6	13.1	25.2	9.2	9.4	7.2
	s ²	6.5	6.1	17.0	16.3	15.1	8.0	6.7	5.2
	s ³	5.5	7.4	11.2	9.4	16.8	10.1	3.8	9.8
EPL II	s ¹	40.8	19.3		18.2	56.8	5.5	10.7	
	s ²	22.9	14.4		28.9	13.6	11.5	12.1	
	s ³	11.1	12.4		8.2	7.7	10.3	14.2	
EPL III	s ¹						9.5	8.4	
	s ²						8.6	4.3	
	s ³						7.4	6.5	
MEAN EPL	all	15.8	11.4	13.6	15.7	22.5	8.9	8.5	7.4

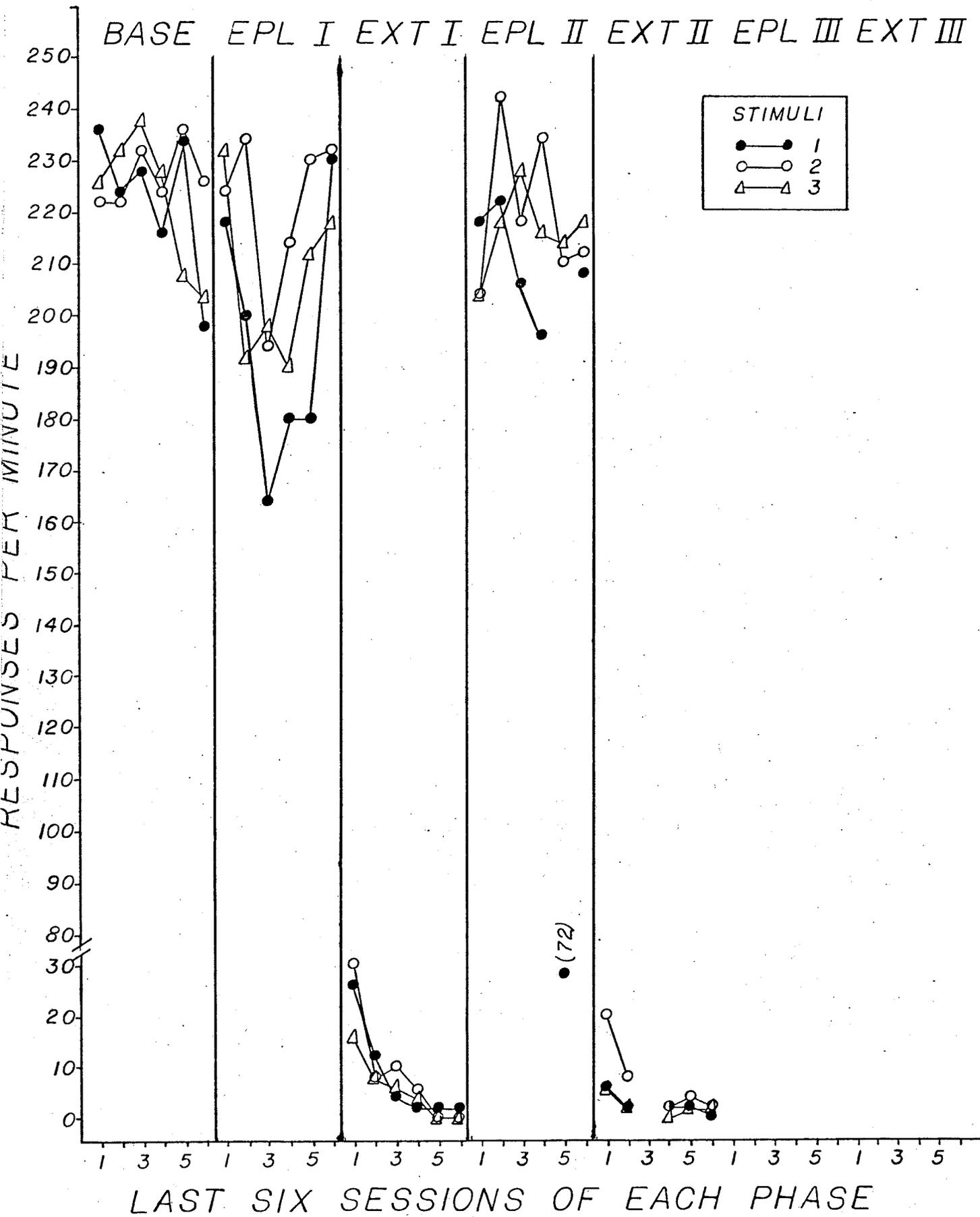
^a Stimuli s¹, s², and s³ were the stimulus compounds correlated with ranges 11, 31, and 51 respectively as described in Table 1 (see METHOD).

FIGURE CAPTIONS

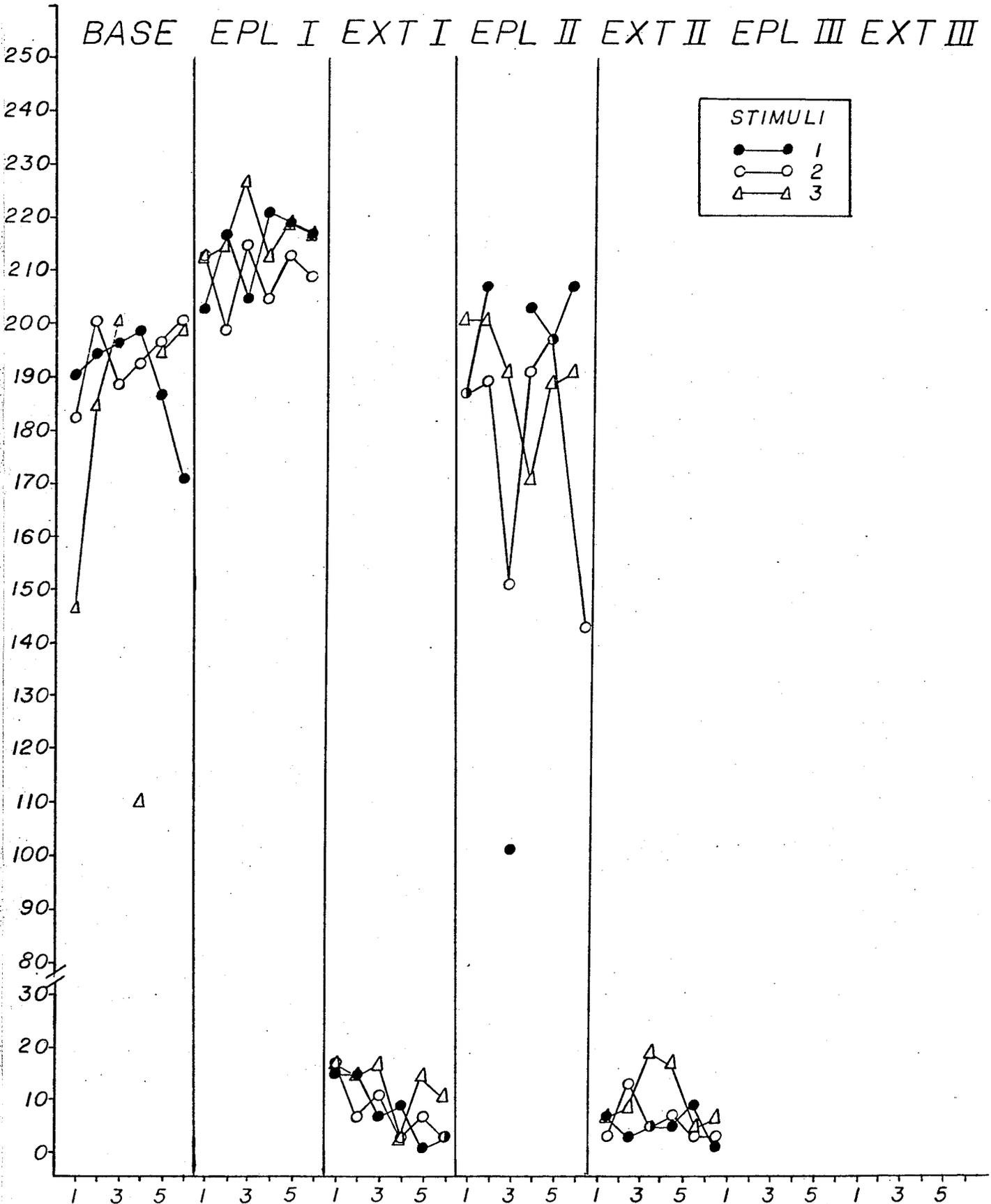
- Fig. 1. Response rate data for subject 5 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).
- Fig. 2. Response rate data for subject 1 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).
- Fig. 3. Response rate data for subject 3 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).
- Fig. 4. Response rate data for subject 4 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).
- Fig. 5. Response rate data for subject 7 for the last six sessions of baseline (BASE) and each experimental (EPL) and extinction (EXT) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).

Fig. 6. Response rate data for subject 8 for the last six sessions of the baseline (BASE) and experimental (EPL) conditions. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).

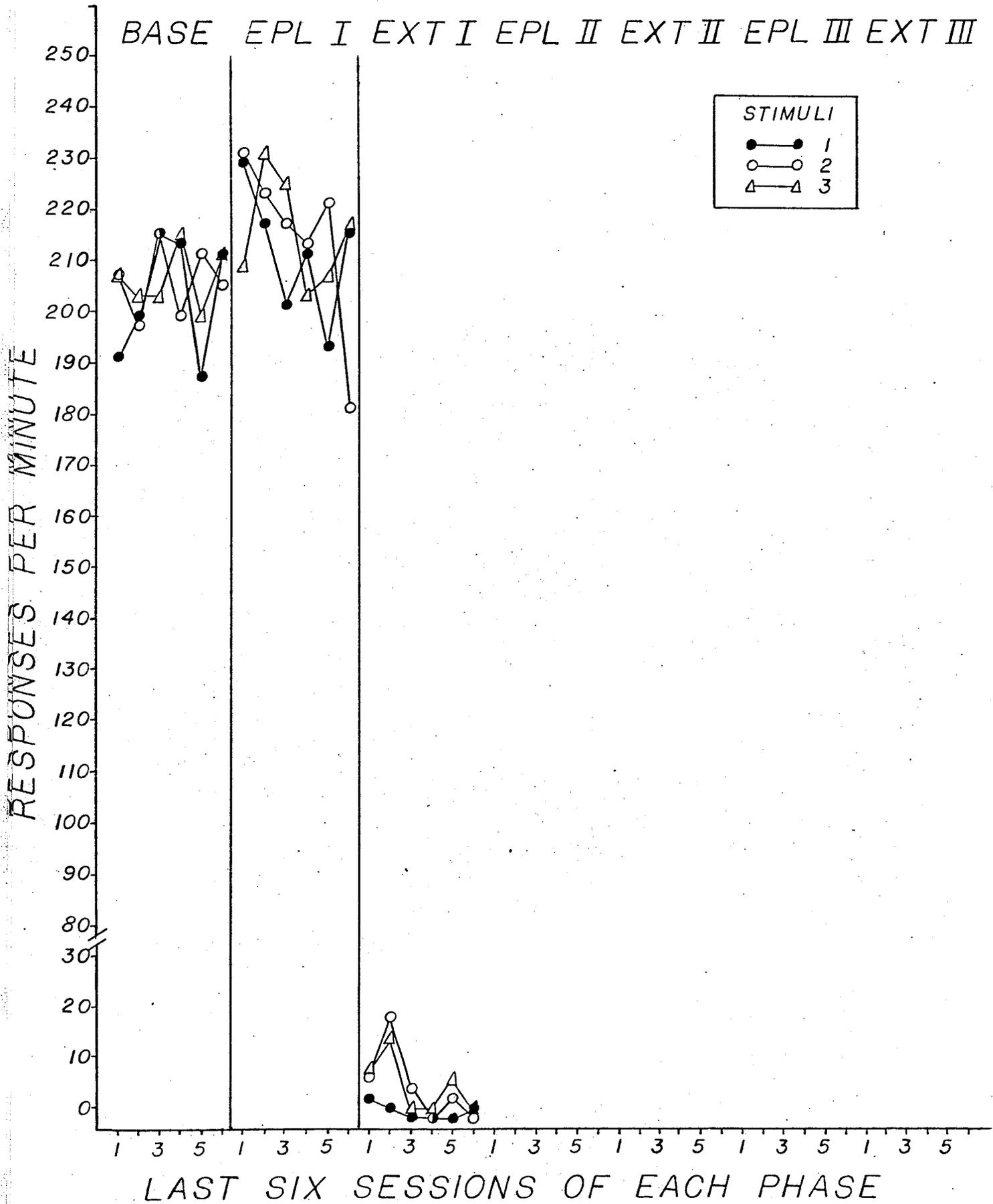
Fig. 7. Mean PRP length for subjects 1, 2, 4, and 5 for the last six sessions of baseline (BASE) and each experimental (EPL) condition. Stimuli 1, 2, and 3 are as described in Table 1 (see METHOD).

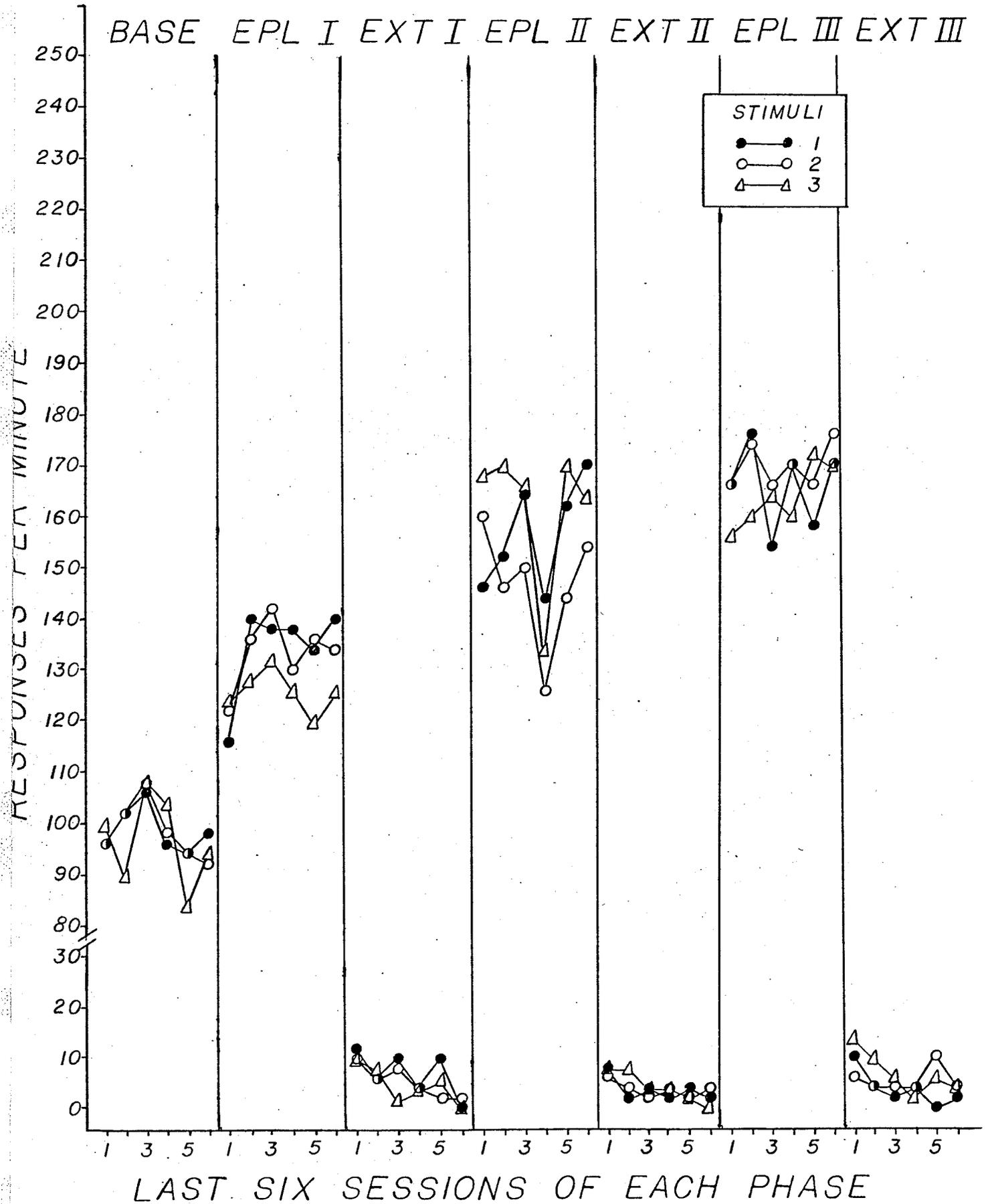


BASE EPL I EXT I EPL II EXT II EPL III EXT III



LAST SIX SESSIONS OF EACH PHASE





BASE EPL I EXT I EPL II EXT II EPL III EXT III

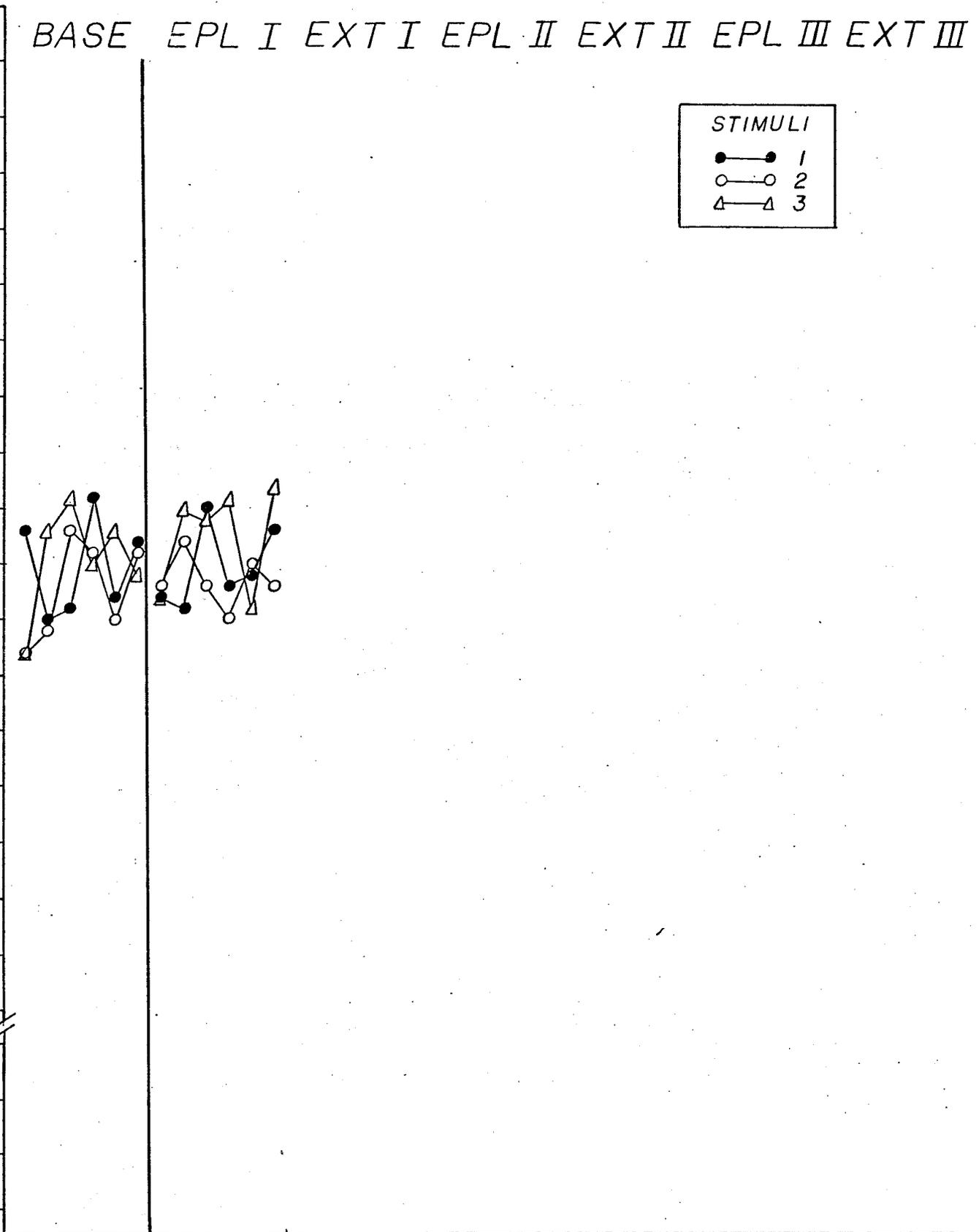
STIMULI
●—● 1
○—○ 2
△—△ 3

HEAT UNITS PER MINUTE

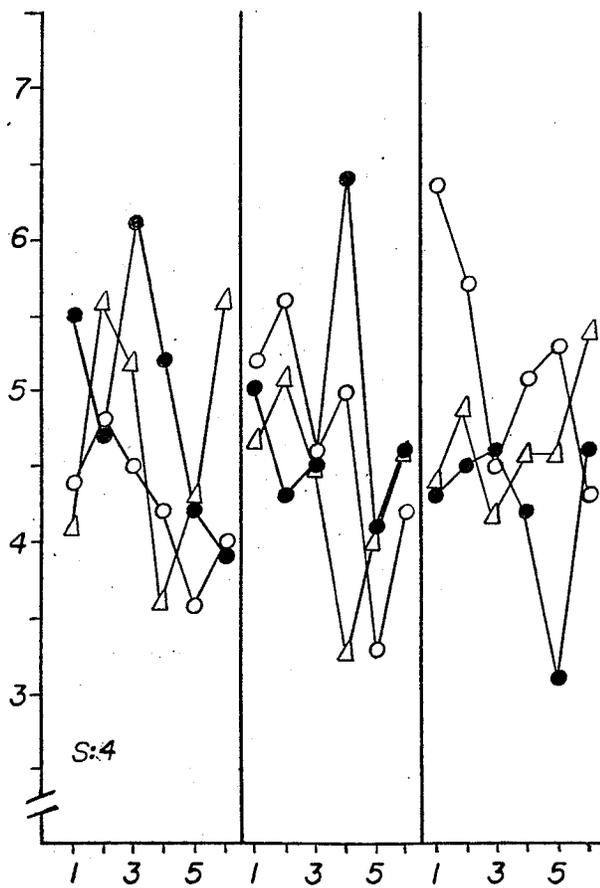
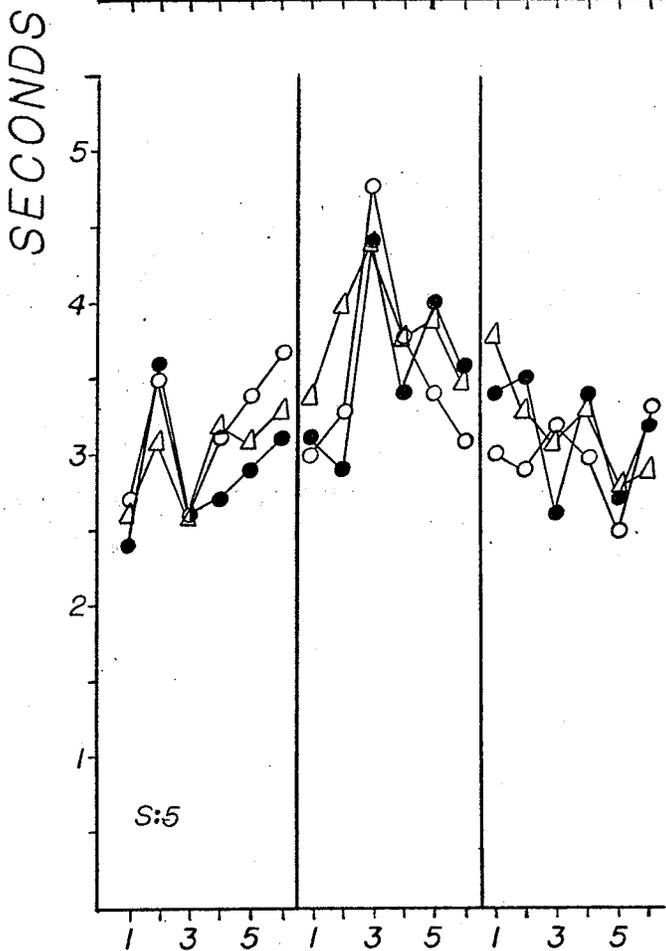
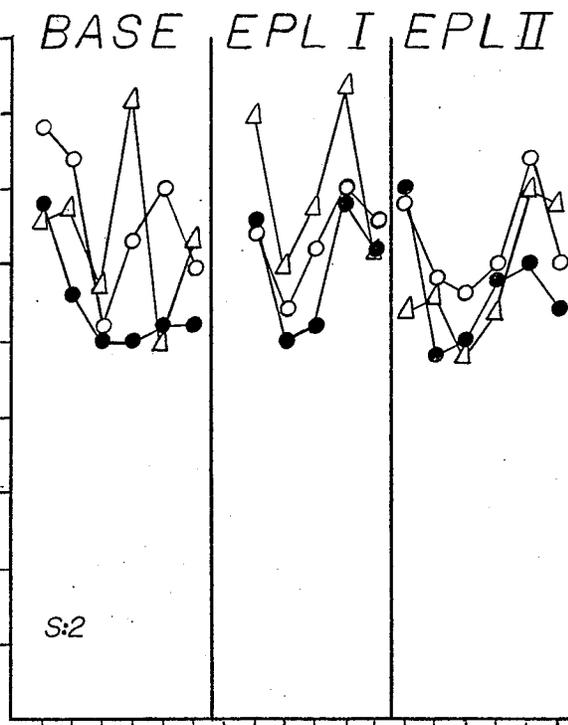
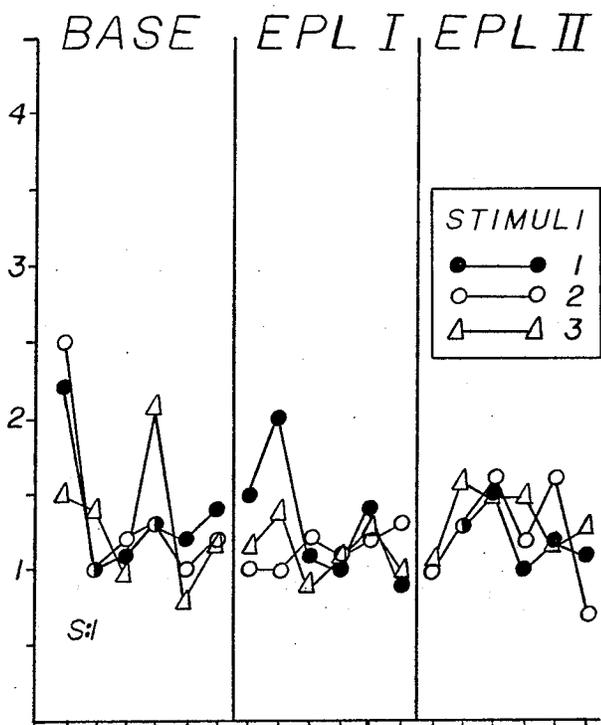
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
30
20
10
0

1 3 5 1 3 5 1 3 5 1 3 5 1 3 5 1 3 5 1 3 5

LAST SIX SESSIONS OF EACH PHASE



Phase	Session	Stimulus 1 (●)	Stimulus 2 (○)	Stimulus 3 (△)
BASE	1	166	144	144
	3	150	148	166
	5	152	166	172
	1	172	162	160
	3	154	166	166
	5	154	150	166
EPL I	1	164	156	154
	3	152	164	170
	5	170	156	168
	1	156	150	172
	3	156	168	172
	5	160	156	152
EXT I	1	166	160	174
	3	156	150	152
	5	156	160	160
	1	166	160	160
	3	166	156	152
	5	166	156	174
EPL II	1	166	156	152
	3	156	160	160
	5	156	160	160
	1	166	160	160
	3	166	156	152
	5	166	156	174
EXT II	1	166	160	152
	3	156	160	160
	5	156	160	160
	1	166	160	160
	3	166	156	152
	5	166	156	174
EPL III	1	166	160	152
	3	156	160	160
	5	156	160	160
	1	166	160	160
	3	166	156	152
	5	166	156	174
EXT III	1	166	160	152
	3	156	160	160
	5	156	160	160
	1	166	160	160
	3	166	156	152
	5	166	156	174



LAST SIX SESSIONS OF EACH PHASE

APPENDIX 3

EXTENDED DISCUSSION OF RESULTS

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 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.

Schedule Effects

FR vs VR. Although seven of eight subjects showed no apparent change in overall response rate when the schedule was switched from mult FR FR FR to mult VR VR VR, there may be some indication of a slight change for subjects 3 and 4 (see Figure 1 in METHOD). The mean overall response rate during the EPL I condition (averaged over components) for subject 3 was slightly higher than during BASE. Such increases, however, have been followed by declines in response rate as with subject 2.

Subject 4 also lacks clearly interpretable data since the mean overall response rate declines in EPL I prior to showing the increase in EPL II. Thus, statements concerning any systematic effects with subjects 3 or 4 are premature.

Green, Sanders, and Squier (1959) noted that the variability of response rate increased with ratio size on an FR but decreased with ratio size on a VR. However, Sidley and Schoenfeld (1964) report an increase in variability with decreases in the probability that a response will be reinforced on a random ratio (RR). Perhaps the slightly different nature of the RR versus the VR (i.e., on the RR each response has the same probability of reinforcement whereas with a VR the ratio requirement is usually predetermined) accounts for the discrepancy although it is hard to see why it might. In any case, neither study compared the variability on FR and VR schedules using the same mean ratio values.

Standard deviation scores were calculated about each component mean (except for EXT conditions). For each subject these scores were then averaged across components and experimental conditions such that a mean standard deviation score was obtained for each subject for BASE conditions and for all the EPLs to which the subject had been exposed, taken together. When these scores were compared for each subject it was found that four subjects showed greater variability in BASE than in EPL conditions. The other four subjects showed the reverse tendency. Although certain deviant points contributed disproportionately to the variability (e.g., see Figures 1 and 2 in APPENDIX 2). These points did not distort or mask any trends. The results therefore, are inconclusive regarding the relationship between the type of ratio (i.e., fixed or variable) and the variability of the response rate.

Sidman (1960) also suggests that ratio behavior, while stable, is frequently insensitive to manipulations due to a large degree of "internal" control. Coupled with the initially high response rates, the overlap of ratio values during the components, and the failure to manipulate any known powerful variables, the lack of differential performance appears quite reasonable. Perhaps the use of non-overlapping ranges (i.e., values chosen only from the extremes of the range) and concurrent schedules would show effects due to range manipulations.

PRP during VR components. The present study failed to find any systematic effects of various ranges upon the duration of PRP. Because this study did not manipulate any variables which have been shown to influence the PRP (see Appendix 1) and since differences among components with respect to response rate were not found, it is not surprising to find no systematic differences among PRPs during the three components.

Variability of response rate during VR components. There appears to be a tendency for more stable performance to occur during components correlated with the largest range. Systematic differences across all three components (i.e., $S^1 > S^2 > S^3$) occurred more often (37.5%) during EPLs than during BASE (12.5%) when observations are considered for all subjects. This tendency is increased to 75% when only the S^1 vs. S^3 comparison is considered. It is important to note, however, that this simplified comparison occurs in 50% of the BASE observations and thus the percentage increase in both cases is 25%.

If the rate of responding, rate of reinforcement, or PRP durations differed among the various ranges in a systematic way then it may have been possible to account for the differences in variability

with respect to those variables in some way. However, they did not. This tendency seems prevalent in all subjects and does not appear to be an artifact of the averaging procedure or of occasionally deviant data. Due to the lack of any other distinct tendencies in the data, it only would be safe to conclude that the relative variability of the response rate on a VR schedule is inversely related to the relative size of the range of a VR schedule.

Rate during extinction components. Following an extensive review of animal literature dealing with extinction, Mackintosh concludes that "Undoubtedly the most important determinant of the rate of extinction, however, is the schedule of reinforcement received during acquisition." and that "Partial reinforcement retards the rate of extinction at least in part because it ensures that subjects have learned to respond in a situation similar to that encountered in extinction (Mackintosh, 1974, pp. 482-483)". Since the conditions in S³ included some very high ratio values (e.g., 55) not required by the other two components it was expected that S³ would show greater RTE. This was the case with only subject 1 (see Figure 1 in METHOD). Likewise, except for subject 1, during extinction the probability of making at least one response during the presentation of the various stimuli which were correlated with the different ranges did not show any systematic trends.

General Conclusions

Manipulation of the range of a VR component in a mult VR30 VR30 VR30 schedule had no systematic effect upon the PRP duration for any subject or upon the overall response rate for seven of eight

subjects. In seven of eight subjects no systematic differences were found in extinction when rate or probability of responding was compared during presentations of stimuli correlated with the various components of the multiple schedule. The data, however, does suggest that an inverse relationship may exist between the variability of the response rate and the range of a VR schedule.

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