4-1980

A Study of the Effects of Changes in Response Requirement on Lever Preference in a Discrete-Trial Choice Procedure

Charles L. Lowe
Western Michigan University

A STUDY OF THE EFFECTS OF CHANGES IN RESPONSE REQUIREMENT ON LEVER PREFERENCE IN A DISCRETE-TRIAL CHOICE PROCEDURE

by

Charles L. Lowe

A Thesis
Submitted to the
Faculty of the Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Psychology

Western Michigan University
Kalamazoo, Michigan
April 1980

ACKNOWLEDGEMENTS

I am indebted to many people. I would like to especially thank Dr. Arthur Snapper for his assistance in all phases of this research. I would also like to thank Dr. Howard Farris for his continuous support of all my academic endeavors and Dr. Jack Michael for providing assistance on numerous occassions. Special thanks are due to my fellow graduate students in Dr. Snapper's laboratory, especially Ken Stephens and Robert Cobez. They provided help on numerous occassions and also provided pleasant distraction. My friend and companion Pam Kies deserves many thanks for her encouragement and patience, not to mention her listening ear. Lastly, I would extend my heartfelt thanks to my parents, Carl and Josie Lowe, for their years of support and encouragement. This work is dedicated to them.

Charles L. Lowe

1314757

LOWE, CHARLES LEMUEL
A STUDY OF THE EFFECTS OF CHANGES IN RESPONSE REQUIREMENT ON LEVER PREFERENCE IN A DISCRETE-TRIAL CHOICE PROCEDURE.

WESTERN MICHIGAN UNIVERSITY, M.A., 1980

University Microfilms International 300 N. ZEEB ROAD, ANN ARBOR, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark ✓.

1. Glossy photographs ________
2. Colored illustrations ________
3. Photographs with dark background ________
4. Illustrations are poor copy ________
5. Print shows through as there is text on both sides of page ________
6. Indistinct, broken or small print on several pages ✓ throughout ________
7. Tightly bound copy with print lost in spine ________
8. Computer printout pages with indistinct print ________
9. Page(s) ________ lacking when material received, and not available from school or author ________
10. Page(s) ________ seem to be missing in numbering only as text follows ________
11. Poor carbon copy ________
12. Not original copy, several pages with blurred type ________
13. Appendix pages are poor copy ________
14. Original copy with light type ________
15. Curling and wrinkled pages ________
16. Other ____

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE | PAGE

INTRODUCTION

In his 1938 description of operant behavior, Skinner presented the Law of Conditioning of Type R. The law stated that "if the occurrence of an operant is followed by presentation of a reinforcing stimulus, the strength is increased" (pg. 21). Since the operant defined by Skinner was not correlated with any identifiable eliciting stimulus, as was the case with respondent behavior, the respondent conditioning measures of reflex strength, such as latency or magnitude, were of little use when applied to operant behavior. In order to establish the notion of strength of operant behavior, Skinner suggested frequency or rate of responding (number of responses per unit time) as the dependent variable. Reinforcement was said to strengthen the behavior it followed, and the strengthening effect was evident in an increase in the frequency of that behavior. In later writings, Skinner (1953, 1961, 1969) identified rate of response as the only appropriate dependent variable from which to infer the probability of response.

Response rate has been shown to be a reliable dependent variable which varies in an orderly manner with fundamental parameters of reinforcement such as frequency and immediacy or delay of reinforcement. More recently, however, a number of experiments have called into question the adequacy of response rate as a sensitive measure of the effects of reinforcement on behavior. Catania (1963), for instance, trained pigeons to key peck on a variable-interval 2-minute schedule of reinforcement (VI 2-minutes) and then varied the duration of grain presentation across groups of experimental sessions. Reinforcement durations were 4.5 seconds, 6.0 seconds, 3.0 seconds, and 4.5 seconds in that order, with training at each duration conducted for a minimum of 10 sessions. Catania found that a change in grain duration from 3.0 to 6.0 seconds had no orderly effect on the rate of key-pecking when the rates of key-pecking were averaged for the last three sessions at each duration and plotted as a function of duration of grain presentation.

In another experiment in which reinforcement magnitude was the independent variable, Powell (1969) trained pigeons to key peck on fixed-ratio (FR) schedules of reinforcement for grain reinforcement. In the presence of a white response key responding produced 2.5 seconds of reinforcement, while in the presence of a red key light responding produced 4.0 seconds of grain reinforcement. During training the key colors and respective reinforcement durations were alternated with each session. Training was continued and the FR response requirement increased across sessions until each pigeon showed consistent differences in the length of post-reinforcement pause under the two durations of grain presentation. During the next

20 sessions the key colors and respective reinforcment durations were alternated as in the training phase of the study. The next 20 sessions were divided into groups of four sessions. In each group of four sessions, one session was conducted in which the reinforcement duration was either 2.5 or 4.0 seconds; the other two sessions were arranged so that the first half of the completed FR's were followed by either 2.5 or 4.0 seconds of grain. Powell found that the post-reinforcement pause was consistently shorter for all birds when key-pecking was reinforced with 4.0 versus 2.0 seconds of grain. For three of the four pigeons, however, mean response rate, calculated after subtraction of post-reinforcement pause and grain presentation time, was found not to increase under conditions where grain presentation was 4.0 seconds. Results similar to those of Catania and Powell have been found by Keesey and Kling (1961).

The validity of response rate as a dependent variable has also been questioned on grounds other than its insensitivity to the magnitude or amount of reinforcement. Nevin (1974) pointed out that frequently there is failure to find an orderly relationship between response rate and resistance to extinction, even though both measures should correlate due to the strengthening effect of reinforcement. Another criticism of response rate was raised by Hodos and Kalman (1963) who argued that since response rate is time dependent, injury, drugs, or surgical preparation may limit an organism's ability to respond at high rates and thus reflect a limited or impaired motor system more than a motivational change produced by reinforcement.

A final criticism of response rate concerns the fact that rate itself is a conditionable aspect of operant behavior. For example, on a differential-reinforcement-of-low-rate schedule (DRL), responding is observed to occur at a low steady rate presumably because interresponse times (IRT's) greater than a contingency specified value are followed by reinforcement. On the other hand, on a variable-ratio (VR) schedule of reinforcement there is a direct proportion between response rate and the number of obtained reinforcements; thus, progressively shorter IRT's are reinforced and a high steady rate of responding is observed. Even though rate of responding must also be considered in relation to the obtained rate of reinforcement in each case, it is clear that response rate does not provide a valid measure of the strength of behavior generated by the DRL schedule.

A number of different methods and dependent variables have been proposed as alternatives to response rate as a measure of the strengthening effect of reinforcement. Uzunoz (1979) identified three such basic procedures, each suggesting its own dependent variable as a measure of the strengthening effect of reinforcement. The procedures were catagorized as: 1) resistance-to-change procedures, 2) concurrent reinforcement procedures, and 3) progressive ratio procedures.

Nevin's (1974) experiments using multiple schedules of reinforcement typify a resistance-to-change approach to the measurement of response strength. In multiple schedules, two successive stimulus conditions, such as different key colors in a pigeon chamber, are correlated with independent schedules of reinforcement. The stimulus condition and correlated schedule of reinforcement define a component in such a schedule. After extended training on a multiple schedule, the rate of responding in each component will stabilize at a level that is controlled by the schedule of reinforcement in that component and the conditions prevailing in the alternated component. Nevin's argument was that if a response weakening operation were applied equally and uniformly to both components of the multiple schedule, the component performance that undergoes the least reduction in responding, relative to baseline rates, may be considered as the stronger of the two performances.

To test this notion, Nevin (1974), trained pigeons to respond on two-component multiple schedules until responding in each component had stabilized. He then introduced a known response-weakening operation, delivery of free-food, during a period between the components. He found that the average rate of responding during the component associated with a variable-interval 1-minute (VI 1-minute) schedule of reinforcement was reduced less, relative to the baseline rate, than the reduction in responding on a VI 3-minute schedule. Thus, according to Nevin, the behavior maintained on the VI 1-minute schedule was to be considered the "stronger" of the two. Similar experiments were conducted in which reinforcement delay, frequency of reinforcement, and magnitude of reinforcement were the independent variables. The results of these studies allowed Nevin to rank-order the strength of responding in different components of multiple schedules on the basis of the relative change in rate of responding from baseline levels. Nevin's procedure is relatively simple and orderly relations were found in the data from each of his experiments. However, as Snapper (1979) noted, the procedure and the interpretation of the relative strengths of responding in each component of the multiple schedules is based on the assumption that a percentage reduction in responding from baseline levels is equivalent across the behaviors maintained by different schedules of reinforcement. In other words, one must assume, for example, that a ten percent (10%) reduction in responding on a VI 3-minute schedule is twice as great as a five percent (5%) reduction in the rate of responding on a VI 1-minute schedule. Hodos (1961) and Hodos and Kalman (1963) proposed the progressive ratio (PR) schedule as a means to measure the strengthening effect of reinforcement. On a PR schedule, the amount of work or the number of responses an organism must emit to obtain reinforcement increases after each delivery of reinforcement. For instance, on a PR 5 schedule, the subject must emit five responses to obtain the first reinforcement, 10 responses to obtain the second reinforcement, 15 responses to obtain the third, and so on until the subject ceases responding altogether for some arbitrary period of time, usually 10 or 15 minutes. The measure of response strength on such a schedule is the final completed ratio the subject completes before "breaking" for the 10 minute period.

Hodos (1961) and Hodos and Kalman (1963) examined the behavior under a number of PR schedules and have obtained orderly results relating the final completed ratio to such independent variables as quantity and quality of reinforcement. Recent research by Uzunoz (1979) illustrated a major problem with the PR schedule and final completed ratio as a sensitive dependent variable, however. Uzunoz observed that when the progressive ratio was increased arithmetically the schedule became increasingly like an FR schedule of reinforcement. As such, the final completed ratio may be more a measure of ratio strain, as the PR is increased, than a measure of the amount of work emitted to obtain reinforcement. When Uzunoz increased the ratio requirement by a fixed percentage following each reinforcement (geometric progressive ratio), instead of a fixed number of responses, he found that the acquisition of PR performance was poor compared to an arithmetic PR. The dependence of the final completed ratio on the rule used to increase the ratio consequently limits the PR procedure as a means of measuring the strengthening effect of reinforcement.

The most recent and well researched attempt to provide an alternative to response rate as the primary dependent variable in operant psychology comes from the study of behavior maintained on concurrent schedules of reinforcement. On a concurrent schedule, two or more reinforcement schedules are in effect simultaneously, with each schedule controlling a separate operant response. For instance, in a two-key pigeon chamber, the schedule on the left key might be a VI 1-minute schedule while, simultaneously, a VI 3-minute schedule is in effect for responding on the right key. Usually, a change-over delay (COD) component is added to concurrent schedules to prevent reinforcement for the behavior of switching from one response key to the other. The COD requires that a minimum period of time elapses between responding on one key and reinforcement delivery on the other.

Using pigeons and concurrent VI schedules similar to that described above, Herrnstein (1961) found a mathematical relationship between the relative response rate on a given key and the obtained relative reinforcement rate on that key. When the data from those experiments were plotted in such terms, a linear relationship was found. In other words, the number of responses made on a key was found to be in direct proportion to the number of reinforcements obtained for responding on that key. Herrnstein referred to this relationship as the matching law and proposed relative rate of responding as the most sensitive measure of the strengthening effect of reinforcement.

de Villiers (1977) reviewed much of the literature relating to Herrnstein's proposal. The research included in his review indicates the generality of the matching relationship in regard to such reinforcement parameters as amount, quality and immediacy. Nevertheless, de Villiers also pointed out that relative response rate is not an "unambiguous" measure of strength. It appears that the matching relationship does not exist in any simple form in other than current VI schedules employing a COD requirement. This consequently limits the generality of the procedure. Also, research by Bovin (1978) and de la Garza (1978) demonstrated the dependency of the matching relationship on the manner in which the timers controlling the VI schedules were arranged. In summary, these limitations argue against relative response rate as a dependent variable from which to infer the strengthening effect of reinforcement.

The several procedures and associated dependent variables reviewed above have all been questioned regarding the degree to which they provide sensitive measures of the strengthening effect of reinforcement. It is interesting to note in this regard that each of the procedures reviewed emphasizes the study of maintained responding. Nevin (1974) noted the emphasis on the study of the variables responsible for maintained behavior and suggested that it may be due, in part, to the difficulties involved in the study of the strengthening effect of reinforcement.

In a similar vein, Snapper (1979) suggested that dependent variables such as response rate and latency and associated procedures were adequate for determining the "threshold" quantities of reinforcement necessary to maintain behavior. Response rate, for instance, is a measure of behavior from which one can infer whether or not a stimulus change is functioning as reinforcement. What is needed, according to Snapper, is a procedure that will allow the comparative assessment of the relative values of different reinforcers. He proposed a symmetrical discrete-trial choice procedure as a possible means of generating such data. Such a choice procedure rests on the assumption that the probability of a response resulting in the stronger reinforcer of two alternatives will always be 1.0, provided that the responding organism has had contact with the contingencies of reinforcement associated with the presentation of each reinforcer.

Johanson (1971, 1975) and Johanson and Schuster (1975, 1977) used a similarly described discrete-trial choice procedure to study drug and dosage preferences in monkeys. In Johanson's 1971 study, the procedure consisted of two parts: a sampling period and a choice period. Monkeys were trained on a procedure in which a red stimulus light was associated with one dosage of cocaine and a green stimulus light was associated with a different dosage of cocaine. In the first sampling period of the study, one of the two stimulus lights was presented on each of five trials. The stimulus alternated with respect to which of two response levers it signalled from trial to trial. Five responses on the signalled lever produced injection of one dosage of cocaine. In the second sampling period the other stimulus was presented in the same manner, but was associated with a different amount of cocaine reinforcement. The sampling periods were followed by a series, "block", of choice trials. On a choice trial, the left-right location of the stimuli was randomly determined and both stimuli were presented at the same time. The subjects were required to emit five responses on one of the levers to produce the associated cocaine reinforcement. Johanson found that training with 0.1 mg/kg and 0.5 mg/kg cocaine dosages resulted in almost exclusive preference for the 0.5 mg/kg dosages on choice trials. The procedure was also used by Johanson and Schuster (1975, 1977) to compare preferences between cocaine and methylphenidate and between cocaine and diethylpropion. In both of these studies cocaine was preferred in a near exclusive fashion.

Johanson (1975) also studied a number of variables which affected dosage preference in the above procedure. In an experiment examining the effects of response requirement on dosage preference, the FR for one alternative dosage remained constant at FR 5. The FR for the other alternative was periodically increased by five, however. Johanson suggested that if the response requirement for the preferred dosage was increased too much that preference would reverse and the lower of the two drug dosages would be preferred instead. Johanson hypothesized further that the difference between response requirements necessary for preference reversal to occur would vary as a function of dosage difference. The data from the study were incomplete and of limited generality due to differences between the subjects. The results from two of four monkeys supported Johanson's hypotheses; the results from the other two monkeys did not.

The procedure used in the present experiment followed directly from Snapper's (1979) description of a symmetrical discrete-trial choice procedure and was also similar in several respects to Johanson's (1975) experiment investigating the effects of response requirement on drug dosage preference. Both procedures required sampling of the reinforcement alternatives but, in the present procedure, sampling trials were equally spaced throughout a session.

Albino rats and water reinforcement were used in the present experiment, whereas Johanson used monkeys as subjects and drug reinforcement to maintain responding. Both studies associated a particular discriminative stimulus with an associated reinforcement but, in the experiment presented here, the discriminative stimuli and associated reinforcement remained fixed in location across trials. Finally, the criteria by which the response requirement was increased differed between experiments. In the Johanson experiment the requirement was increased by five. In the present experiment, the FR requirement was increased by one or two, and only after stringent stability criteria had been met.

In summary, the present experiment was an examination of the effects of increases in FR response requirements on preference for reinforcement alternatives in a discrete-trial choice procedure. The experiment was designed to study choice for a given alternative as the FR requirement for that alternative was systematically increased, decreased, and increased again across experimental sessions. The need for the present study was indicated by the fact that, currently, little data exist on factors affecting preference in discrete-trial choice procedures similar to the one described here. Furthermore, in order for the present procedure to prove useful in future attempts to determine the relative values of reinforcements differing in quantity or quality, the effects of independent variables, such as response requirements, need to be initially examined.

METHOD

Subjects

Five, experimentally naive, male albino rats served as subjects. The rats were obtained from the Upjohn Company of Kalamazoo, Michigan and were approximately 90 days old at the start of experimentation. The subjects were individually housed and were maintained at approximately 85% of their free-feeding body weight by restricting their daily access to water. Water, occasionally supplemented with multi-vitamins, was made available for 10 to 15 minutes each day. The animals always had free access to Purina Laboratory Chow in the home cages.

Apparatus

Five identical chambers were used. The interior dimensions of each chamber were 20 cm. long, 13 cm. wide, and 15 cm. deep. The ceiling and walls were composed of Plexiglas and the interior wall surfaces were covered with aluminum sheets. The floor of each chamber consisted of four tubular rods, 1.9 cm. in diameter. The tubular rods were spaced 3.8 cm. apart, center to center.

On the right wall, approximately midway between the sides and 2.54 cm. above the floor, a 2.54 cm. diameter circular opening was located. The opening provided occasional access to a dipper which normally rested in a reservoir containing water. When operated, the dipper contained a drop of water. Located approximately 9 cm. above the floor two additional openings were located. Each was 2.54 cm. in diameter and spaced 6 cm. apart, center to center. Flat response levers (Compound Rodent Lever, Model 121-05 BRS-LVE) could be inserted through these holes. When inserted, the response levers were designed to close a microswitch when a minimum downward force of .2N was applied. When the lever(s) were not in use the circular openings could be covered with a flat aluminum plate. Two additional circular openings, each 1.85 cm. in diameter and located 5 cm. apart, center to center, were located 12.5 cm. above the floor. Behind each hole an independently operated light was located which was covered with an amber lens cap.

The front wall of each chamber was hinged to serve as a door. The left wall of each chamber was featureless. On the back wall, a circular opening, 2.5 cm. in diameter, was located 7.5 cm. above the floor and 7.5 cm. from the left wall. Behind the opening an independently operated light, covered with a red lens cap, was located. Also mounted behind the back wall was an auditory stimulus source (Sonalert Model SC 628) which could deliver one of four intensities of a 2900 Hz tone.

Each experimental chamber was enclosed in a sound-attenuating cabinet. Each cabinet contained a houselight and fan. Extraneous sounds were masked by white noise presented through a speaker connected to a Grason-Stadler (Model 901 B) white noise generator.

Programming of experimental conditions and recording of data was controlled by a Digital Equipment Corporation PDP 8/E computer. The controlling software, SUPERSKED (Snapper and Inglis, 1979), allowed for programming and data analysis while experimentation was in progress. The computer was located in a room adjacent to the experimental chambers. The experimental chambers were interfaced to the computer via an interface provided by State Systems, Inc. of Kalamazoo, Michigan.

Procedure

The subjects were initially dipper-trained. Every 90 seconds the dipper dropped into the water reservoir for one second and then returned to the "up" position which provided the subjects with access to a drop of water on the end of the dipper arm. Coincident with dipper operation and for four seconds afterwards, a tone was presented. Also at the time of dipper operation and for four seconds afterwards, the amber light above the right response lever, which was normally illuminated, went out. This sequence of events occurred every 90 seconds or following a lever press. In the event that lever pressing developed so that 10 responses occurred between free dipper-presentations, the remainder of the dipper presentations were then responsecontingent. Dipper-training sessions terminated after 100 dipper presentations.

Responding was then hand-shaped by the method of successive approximations. The amber light above the right response lever was normally illuminated except during dipper presentations. When a suitable response was emitted, the amber light above the right lever was extinguished, the dipper dropped into the water reservoir for one second, and then returned to the original "up" position. Also, at the time of dipper operation and for four seconds afterwards, a tone was presented. Response-shaping sessions terminated after 100 dipper presentations.

Once lever pressing was shaped, the procedure was changed to a continuous-reinforcement procedure similar in every respect to the hand-shaping procedure except for the manner in which the dipper was presented. In the continuous-reinforcement procedure, the dipper normally remained below the surface of the water in the reservoir. When a lever press occurred, the lever light was extinguished for five seconds; a tone was presented for five seconds; and the dipper was raised to the "up" position for five seconds with all events occurring concurrently. Thereafter, the amber light and dipper returned to the original conditions until another response occurred. Continuous-reinforcement sessions terminated following 100 dipper presentations.

After several sessions exposure to the continuous-reinforcement procedure, the response requirement was gradually increased from fixed-ratio one (FR 1) to FR 3 within the same session. The first and second responses within the FR produced a 0.5 second "blip" of a tone, otherwise the procedure was the same as the continuous-reinforcement procedure described above. This procedure was in effect for a minimum of two sessions or until performance was satisfactory as evidenced by short latencies to the first response at the beginning of a trial and short inter-response-times (IRT's) within the FR.

Trial-training constituted the next phase of training. During trial-training an inter-trial-interval (ITI) and a limited-hold contingency on initiation of responding were introduced. At the beginning of trial-training, the ITI was very short and amounted to only few seconds in which the chamber was darkened. The ITI was also initiated after a period of two minutes during which no responding occurred. Across sessions, the length of the ITI was gradually increased up to a final length of 30 seconds. Increases in ITI length were based on the absence of excessively long latencies to the first response at the end of the ITI and the emission of few responses during the ITI.

During trial-training the left response lever was introduced for the first time. Access to the right and left response levers was alternated between sessions; for instance, during the first session of trial-training, the right lever was present throughout the session, during the second session the left response lever was present throughout the session and so on.

In the final phase of training both response levers were present at the same time. On each trial, however, only one lever was activated in the sense of having a FR schedule of reinforcement programmed on it. In the final phase of trial-training, the sequence of events was as follows. A light was illuminated above one of the response levers at the beginning of a trial. Responses on that lever produced a 0.5 second "blip" of a tone, and, after completion of the FR, water presentation. Responses to the inactive lever had no effect but were recorded. When the left lever was activated on a trial, the light above the left response lever flashed on and off at a rate of five cycles per sec. When reinforcement was delivered for responding on the left lever a tone was also turned on and off at a rate of five cycles per sec. If the right lever was assigned on a trial, then the light above that response lever was illuminated throughout the trial. Water presentation at the end of the trial was accompanied by a continuous tone presentation. Since the response requirements on the levers were to be unequal during the first experimental condition, the FR requirements during trial training were also unequal, with FR 2 and FR 5 for the left and right levers, respectively. This type of trial, in which only one response lever was activated, was called a single-alternative trial.

A modified state diagram of the final trial procedure is presented in Fig. 1. During the experimental phase of the study, a session was divided into 10 blocks of five trials each. The first four trials of each block were single-alternative trials in which the activated response lever alternated between the left and right response levers, both of which were present. The fifth trial of each five-trial block was a choice trial in which both response levers and respective lights were initially activated and illuminated. When a response was made on one lever, the other lever was immediately deactivated and the subject was required to complete the FR schedule on the lever initially responded to. The FR schedules on the response levers varied from session to session, but remained fixed within a session.

As noted above, the initial response requirements were FR 2 on the left lever and FR 5 on the right lever. Changes in the response requirement on the left variable lever were made on the basis of daily inspection of the proportion of choice trials in which the left lever was chosen. The FR on the left response lever was changed by a value of one according to the following criteria: 1) If exclusive preference on the choice trials was shown for either

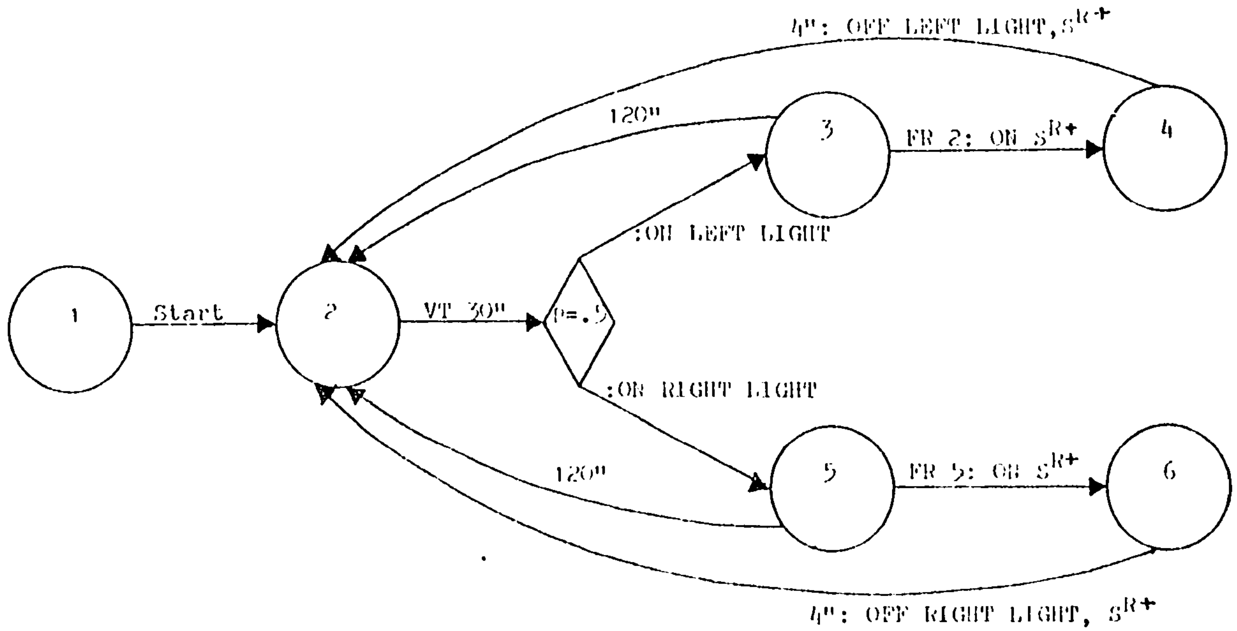
1
Start
2
VT 30"
P=.5
:ON LEFT LIGHT
:ON RIGHT LIGHT
3
FR 2: ON S^{R+}
4
4": OFF LEFT LIGHT, S^{R+}
120"
5
FR 5: ON S^{R+}
6
4": OFF RIGHT LIGHT, S^{R+}
120"

FIGURE 1

response lever. Exclusive preference was defined as responding on either lever on nine of 10 choice trials within a session. 2) If exclusive preference was not observed but stability between sessions was satisfactory. Stability was defined as the absence of any increasing or decreasing trend in the proportion of left response lever choices across sessions at the same FR value. The FR on the left lever was never changed following a session in which responses were not made on all choice trials. The ratio values on the left lever were increased by one when appropriate, until the proportion of left lever choices descreased to 0.1; in other words, until exclusive preference for the right response lever was observed on the 10 choice trials within a session. At that point, the ratio value on the left response lever was decreased by a value of one between sessions, according to the conditions of the stability criteria, until subjects again exhibited exclusive preference for the left response lever on choice trials. A final series of ratio increases by one, on the left lever was then performed until, once again, exclusive preference for the right lever on the choice trials was observed within a session. At that point, the first experimental condition was terminated.

The second experimental condition of the study was the same in most respects as the first. The following differences were present, however. The initial FR values on the left response lever were selected in such a manner as to result in few ratio increases on the left lever before exclusive preference for that lever was no longer present. The change was made in order to eliminate unnecessary sessions at FR values where exclusive preference for the left lever was highly likely. The ratio value on the right lever was constant throughout the second condition of the study at FR 10. In an effort to make the procedure more efficient, the following changes in procedure were made: The criteria for changing the FR value on the left (variable) lever were modified so that the FR was increased by two during the initial increasing series, versus a value of one during the first experimental condition. Also, the stability criteria were changed. During the second condition of the study, satisfactory stability was defined as left lever choice proportions from two consecutive sessions at the same FR value which differed by no more than 20%. For example, a left lever choice proportion of 0.5 on day one followed by a left lever choice proportion 0.7 on day two was considered stable and the left lever FR was increased/decreased the following session. In all other respects, the procedure in the second condition of the study was the same as in the first condition.

RESULTS

Data from an individual session in the first condition are presented in Table I. The data were obtained from Rat 262 and were selected from the initial ascending series of sessions in which the ratio on the left response lever was increased by one across sessions. The data were obtained when the left and right levers were FR 4 and FR 5, respectively. The latencies presented are the length of time, in seconds, from the onset of a lever light(s) to the first response on a trial. As can be seen in Table I, the latencies to the first response are generally shorter on the left lever single-alternative trials. A comparison of the mean latencies for the session, however, shows that the average latency to the first response on left lever single-alternative trials was 7.53 seconds compared to 6.25 seconds for right lever single-alternative trials. The mean latency for the left lever trials was inflated by a latency of 79.4 seconds on Trial 37. The median latencies were 2.2 and 4.6 seconds for the left and right levers, respectively. A sequential inspection of the latencies in Table I shows a tendency towards longer latencies on single-alternative trials as the number of trials completed increased. On choice trials, Rat 262 responded to the left lever exclusively during the session. The mean latency on the 10 choice trials was 6.01 seconds. The median latency on the choice trials was 2.6 seconds.

TABLE I

LATENCIES TO THE FIRST RESPONSE FOR RAT 262

Exclusive Preference For The Left Lever: FR 4 Left, FR 5 Right					
Blocks of 5 Trials	Single Alternative Trials				Choice Trials
1	2.4 Left	4.4 Right	1.7 Left	4.1 Right	0.9 Left Choice
2	1.8 Right	2.1 Left	5.7 Right	1.6 Left	- Left Choice
3	1.6 Left	5.3 Right	3.4 Left	1.4 Right	2.6 Left Choice
4	1.6 Left	6.6 Right	7.2 Left	4.3 Right	2.6 Left Choice
5	1.8 Left	3.9 Right	1.9 Left	2.6 Right	1.9 Left Choice
6	1.8 Left	2.7 Right	2.1 Left	4.0 Right	3.5 Left Choice
7	2.3 Left	6.0 Right	5.2 Left	5.0 Right	6.1 Left Choice
8	2.1 Left	4.7 Right	79.4 Left	3.8 Right	2.6 Left Choice
9	19.7 Right	3.3 Left	11.9 Right	2.9 Left	10.8 Left Choice
10	5.0 Right	7.3 Left	22.1 Right	18.9 Left	3.1 Left Choice

A series of conditional probabilities for Rat 262 for the same session are presented at the top of Table III. Since the left lever was responded to first on each of the 10 choice trials, it is not possible to determine whether or not lever preference on the choice trials was influenced by the left or right location of the preceding single-alternative trial.

Table II shows data for Rat 262 when the left and right levers were FR 7 and FR 5, in that order. These data were obtained from a session in which neither lever was prefered exclusively; the left lever was responded to on seven of the 10 choice trials. The latencies to the first response on left lever single-alternative trials do not appear to differ greatly from the latencies obtained on right lever single-alternative trials. The median latency for left lever trials was 3.0 seconds compared to 4.6 seconds for right lever single-alternative trials. For the seven choice trials in which the left lever was selected, the median latency was 3.4 seconds. The mean latency for the three right lever choices was 4.23 seconds. Table II again shows that the latencies for both left and right single-alternative trials tended to become longer as the session progressed.

The conditional probabilities presented in the bottom part of Table III were obtained using the same data presented in Table II. Table II and the associated condi-

TABLE II

LATENCIES TO THE FIRST RESPONSE FOR RAT 262

Nonexclusive Preference For The Left Lever: FR 7 Left, FR 5 Right					
Blocks of 5 Trials	Single Alternative Trials				Choice Trials
1	3.0 Left	4.1 Right	1.3 Left	5.5 Right	1.1 Left Choice
2	2.3 Left	5.9 Right	1.0 Left	1.7 Right	2.1 Left Choice
3	1.1 Left	2.9 Right	1.0 Left	7.7 Right	4.8 Left Choice
4	6.0 Right	4.1 Left	2.0 Right	4.4 Left	5.0 Right Choice
5	4.3 Left	2.5 Right	2.0 Left	2.2 Right	3.3 Left Choice
6	3.2 Left	20.0 Right	1.5 Left	5.3 Right	4.8 Left Choice
7	4.5 Left	5.0 Right	2.7 Left	3.8 Right	5.4 Right Choice
8	33.5 Left	1.9 Right	23.2 Left	10.2 Right	2.3 Right Choice
9	4.8 Left	12.8 Right	27.8 Left	19.7 Right	7.9 Left Choice
10	2.8 Left	5.8 Right	2.6 Left	3.7 Right	1.9 Left Choice

TABLE III

CONDITIONAL PROBABILITIES FOR RAT 262

Exclusive Preference For The Left Lever: FR 4 Left, FR 5 Right		
p (Right Choice: Preceding Right Trial)	= 0/7	= 0.00
p (Left Choice: Preceding Right Trial)	= 7/7	= 1.00
p (Right Choice: Preceding Left Trial)	= 0/3	= 0.00
p (Left Choice: Preceding Left Trial)	= 3/3	= 1.00
p (Preceding Right Trial: Left Choice)	= 7/10	= 0.70
p (Preceding Left Trial: Left Choice)	= 3/10	= 0.30
p (Preceding Right Trial: Right Choice)	= 0/0	= 0.00
p (Preceding Left Trial: Right Choice)	= 0/0	= 0.00
Nonexclusive Preference For The Left Lever: FR 7 Left, FR 5 Right		
p (Right Choice: Preceding Right Trial)	= 2/9	= 0.22
p (Left Choice: Preceding Right Trial)	= 7/9	= 0.78
p (Right Choice: Preceding Left Trial)	= 1/1	= 1.00
p (Left Choice: Preceding Left Trial)	= 0/1	= 0.00
p (Preceding Right Trial: Left Choice)	= 7/7	= 1.00
p (Preceding Left Trial: Left Choice)	= 0/7	= 0.00
p (Preceding Right Trial: Right Choice)	= 2/3	= 0.66
p (Preceding Left Trial: Right Choice)	= 1/3	= 0.33

tional probability values in Table III show that a right single-alternative trial was presented on nine of the 10 single-alternative trials immediately preceding choice trials. The tables show that the conditional probability of a left choice following a right lever single-alternative trial was 0.78. Of the three right lever choices, two occured immediately following a right lever single-alternative trial. It is not clear from these data to what extent the left or right location of the previous single-alternative trial affected lever preference on choice trials during that session.

Individual session proportion of choices for the left lever are plotted as a function of the response requirement on the left lever in Figure 2. The figure shows daily data for Rat 262 in 30 consecutive sessions in the first condition of the study. Each data point represents the proportion of times the left lever was chosen during the 10 choice trials presented that session. Figure 2 shows that the number of times the left lever was chosen during a session declined as the ratio on the left lever was increased across sessions. The stability criteria for increasing or decreasing the left lever ratio was frequently met within two sessions. Exceptions occurred when the left lever was FR 7, FR 8, and FR 9. A total of 13 sessions were required to increase the ratio from FR 7 to FR 10. Of those 13 sessions, six were

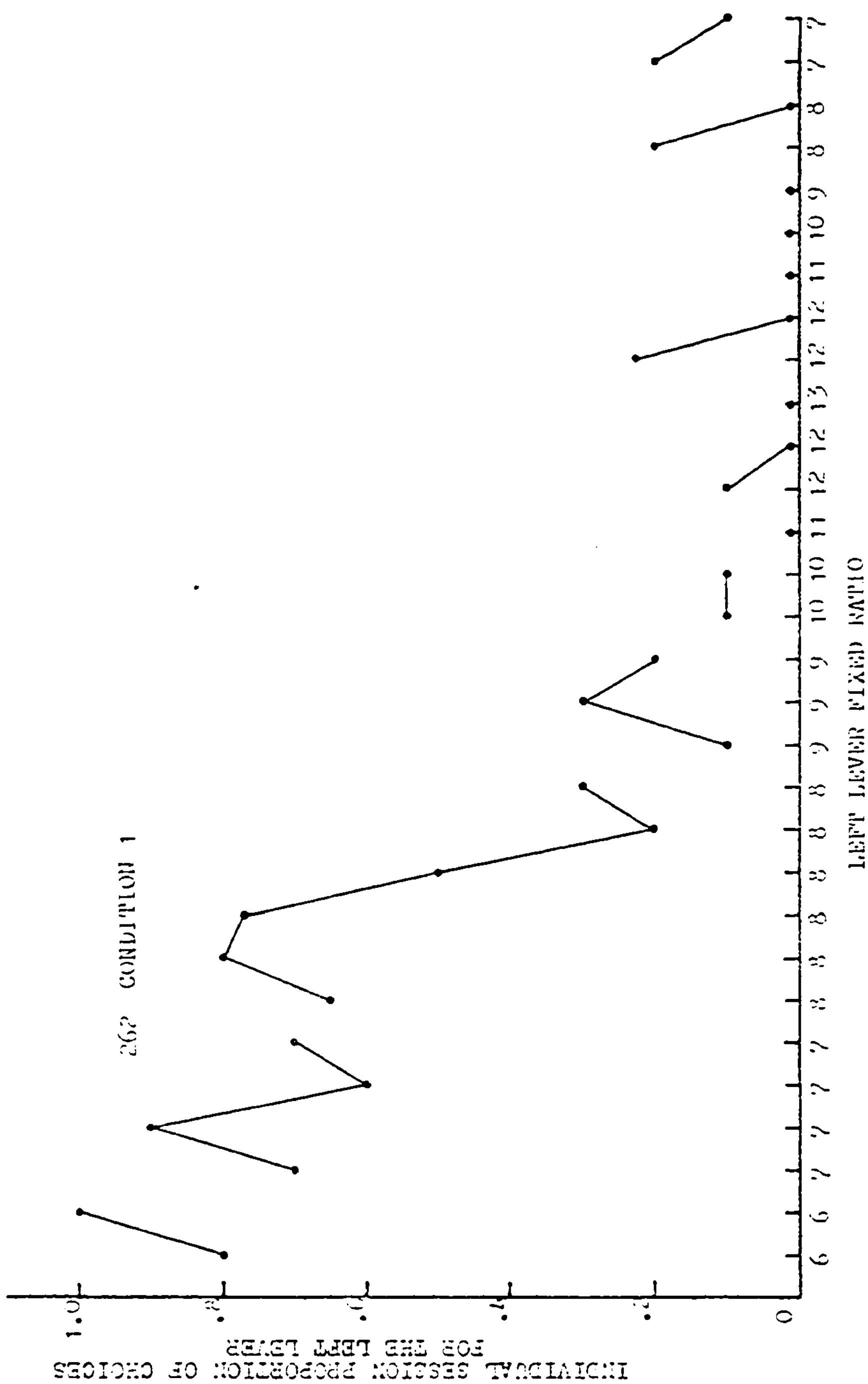
262 CONDITION 1
INDIVIDUAL SESSION PROPORTION OF CHOICES FOR THE LEFT LEVER
1.0
.8
.6
.4
.2
0
6 6 7 7 7 7 7 8 8 8 8 8 8 9 9 9 10 10 11 12 12 13 12 12 11 10 9 8 8 7 7
LEFT LEVER FIXED RATIO

FIGURE 2

required in order to meet the stability criteria at FR 8. The proportion of choices for the left lever ranged from 0.8 to 0.2.

In Figure 3 the proportions of choice for the left lever are plotted as a function of the left lever response requirement for the entire first condition of the study for Rat 262. Each data point represents the average proportion of choices for the left lever from the last two sessions at each ratio value. Data points indicating exclusive left or right lever preference on choice trials represents the data from one session only since the stability criteria for increasing the left lever ratio was met in that session. Figure 3 shows clearly that the proportion of choices for the left lever decreased in a systematic fashion as the left lever response requirement was increased across sessions. During the initial (ascending) series of sessions in which the left lever ratio was increased by one, choices for the left lever declined in a near linear manner. The decline in preference for the left lever on choice trials was distributed fairly evenly across ratio values, except for the decline in preference observed from FR 7 to FR 8. It should be noted in this regard that Figure 2 shows a great deal of between session variability in proportion of choices for the left lever at those ratio values. When the response requirements on the levers were equal at FR 5, the pro-

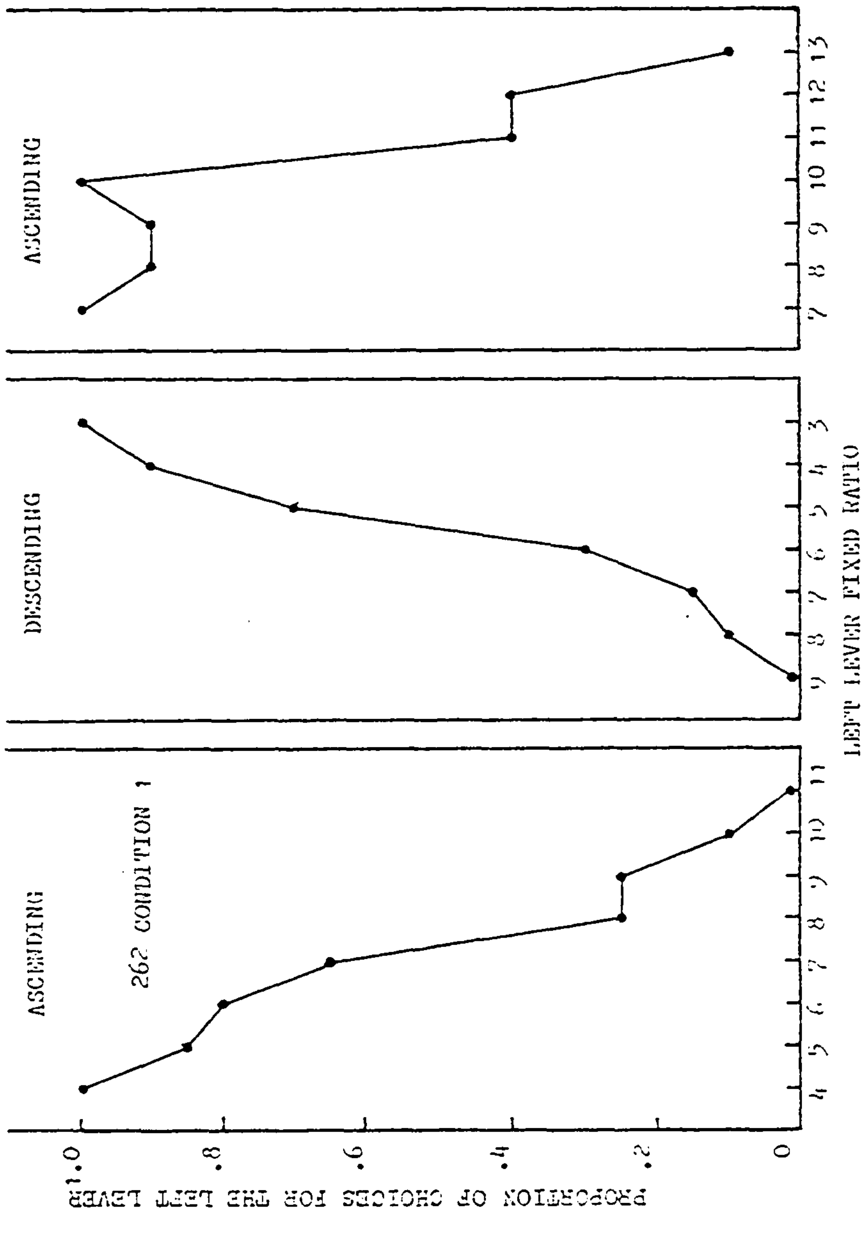
ASCENDING
262 CONDITION 1
DESCENDING
ASCENDING
LEFT LEVER FIXED RATIO
PROPORTION OF CHOICES FOR THE LEFT LEVER
1.0
.8
.6
.4
.2
0
4 5 6 7 8 9 10 11
9 8 7 6 5 4 3
7 8 9 10 11 12 13

FIGURE 3

portion of choices for the left lever was 0.85. Exclusive preference for the right lever occurred when the left lever was FR 10 and the right lever was FR 5.

The second panel of Figure 3 shows data from the series of sessions in which the left lever ratio was decreased by one between sessions. Again the proportion of choices for the left lever varied almost linearly as a function of changes in the left lever response requirement; in this instance the proportion of choices for the left lever increased across sessions. As in the initial series of sessions, the increase in preference for the left lever was distributed fairly equally across the different ratio values. Once again, however, a large change in left lever preference was observed to occur as a function of a unit change in FR. This occurred between FR 6 and FR 5 when the proportion of choice for the left lever changed from 0.25 at FR 6 to 0.70 at FR 5.

The data presented in the third panel of Figure 3 were obtained during the second series of sessions in which the left lever response requirement was increased. The data in that series of sessions were more variable. Exclusive preference for the left lever was observed when the response requirements were FR 7 and FR 5 for the left and right levers, respectively. At FR 8 and FR 9 the averaged proportion of choices for the left lever was 0.85. When the left lever was changed to FR 10, the proportion of choices for the left lever again increased to 1.0. Between FR 10 and FR 11 the proportion of choices for the left lever declined from 1.0 to 0.4. The proportion of choices for the left lever did not decrease from 0.4 when the left lever ratio was changed to FR 12, but did decrease to 0.05 when the left lever response requirement was FR 13.

Averaged latencies to the first response on left and right single-alternative trials during the first condition are presented in Figure 4 and plotted as a function of the ratio on the left lever for Rat 262. Each data point represents the mean of the latencies to the first response for the 20 left and right single-alternative trials in each session. During the first series of increases in the left lever ratio, Figure 4 shows that the latencies obtained on both left and right single-alternative trials were quite variable. In general, the latencies to the first response on right lever single-alternative trials were longer than left lever single-alternative trials. The second panel of Figure 4 presents data from the series of sessions in which the left lever ratio was decreased between sessions. The latencies during this portion of the first condition appeared to be much less variable. The latencies for left lever single-alternative trials tended to decrease across sessions as the left lever ratio was decreased from FR 9 to FR 3.

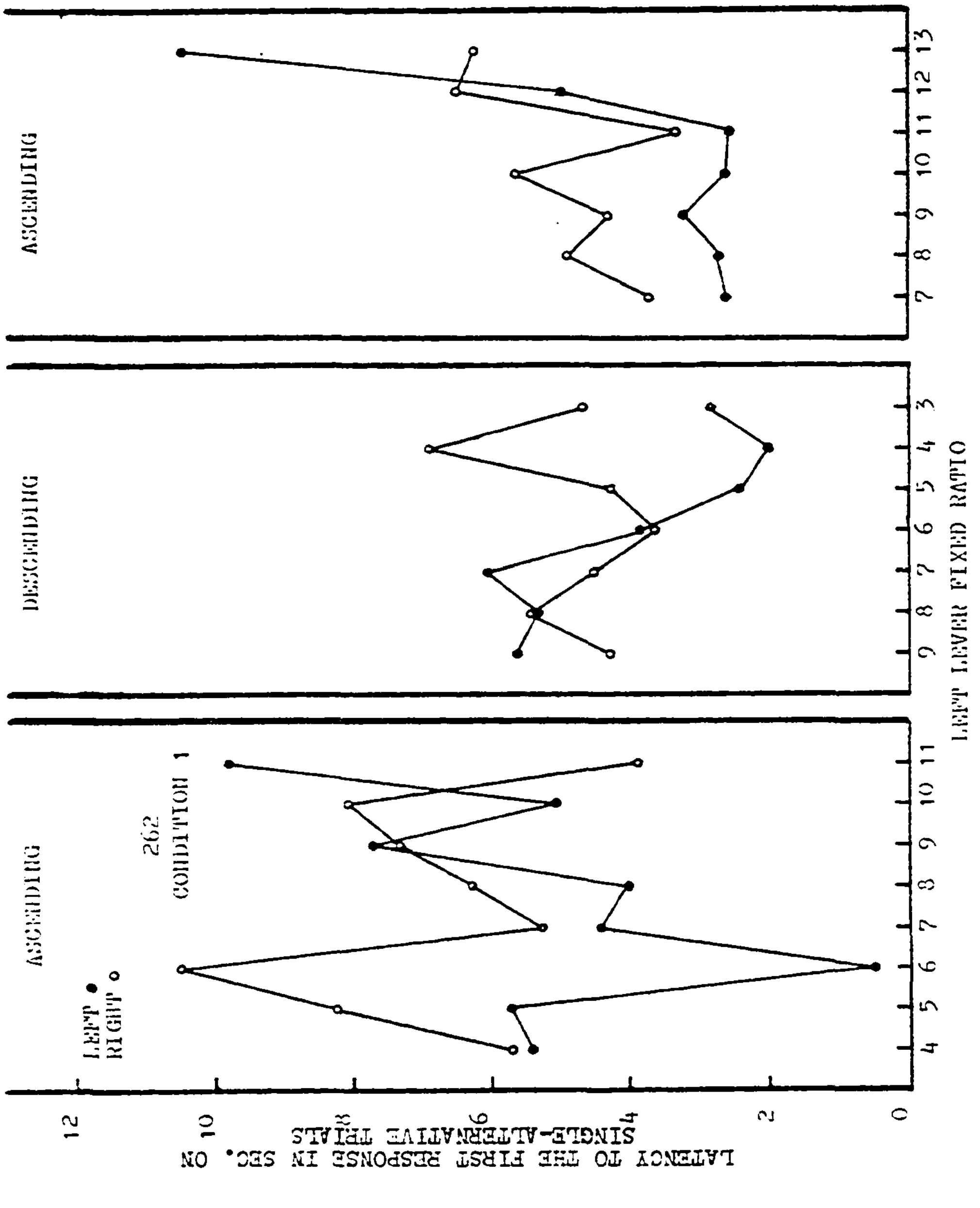
ASCENDING
DESCENDING
ASCENDING
LEFT ●
RIGHT ○
262
CONDITION 1
LATENCY TO THE FIRST RESPONSE IN SEC. ON SINGLE-ALTERNATIVE TRIALS
LEFT LEVER FIXED RATIO
0
2
4
6
8
10
12
4 5 6 7 8 9 10 11
9 8 7 6 5 4 3
7 8 9 10 11 12 13

FIGURE 4

Increasing or decreasing trends in latency length were not observed for right lever single-alternative trials across the same ratio values. The latency values in the third panel of Figure 4 are from the second series of sessions in which the left lever ratio was increased. The latencies obtained during those sessions were more stable than in the two previous series of sessions. Left lever latencies were clearly shorter than right lever latencies, with the exception of the latencies obtained at FR 13.

Latencies to the first response on choice trials during the first condition are presented for Rat 262 in Figure 5. A missing data point for the left or right lever indicates that the subject responded exclusively to one of the levers on the choice trials during that session. The pattern of lengths and variability in the choice trial latencies roughly resembled those observed for single-alternative trials. While the length of choice trial latencies did not appear to be related in any systematic way to the value of the left lever ratio during the initial series of sessions, the second panel of Figure 5 shows that both left and right latencies on choice trials decreased as the left lever ratio was decreased. The latencies observed for left lever choices in the third panel of the figure suggest a trend toward increasingly longer latencies as the left lever ratio was increased.

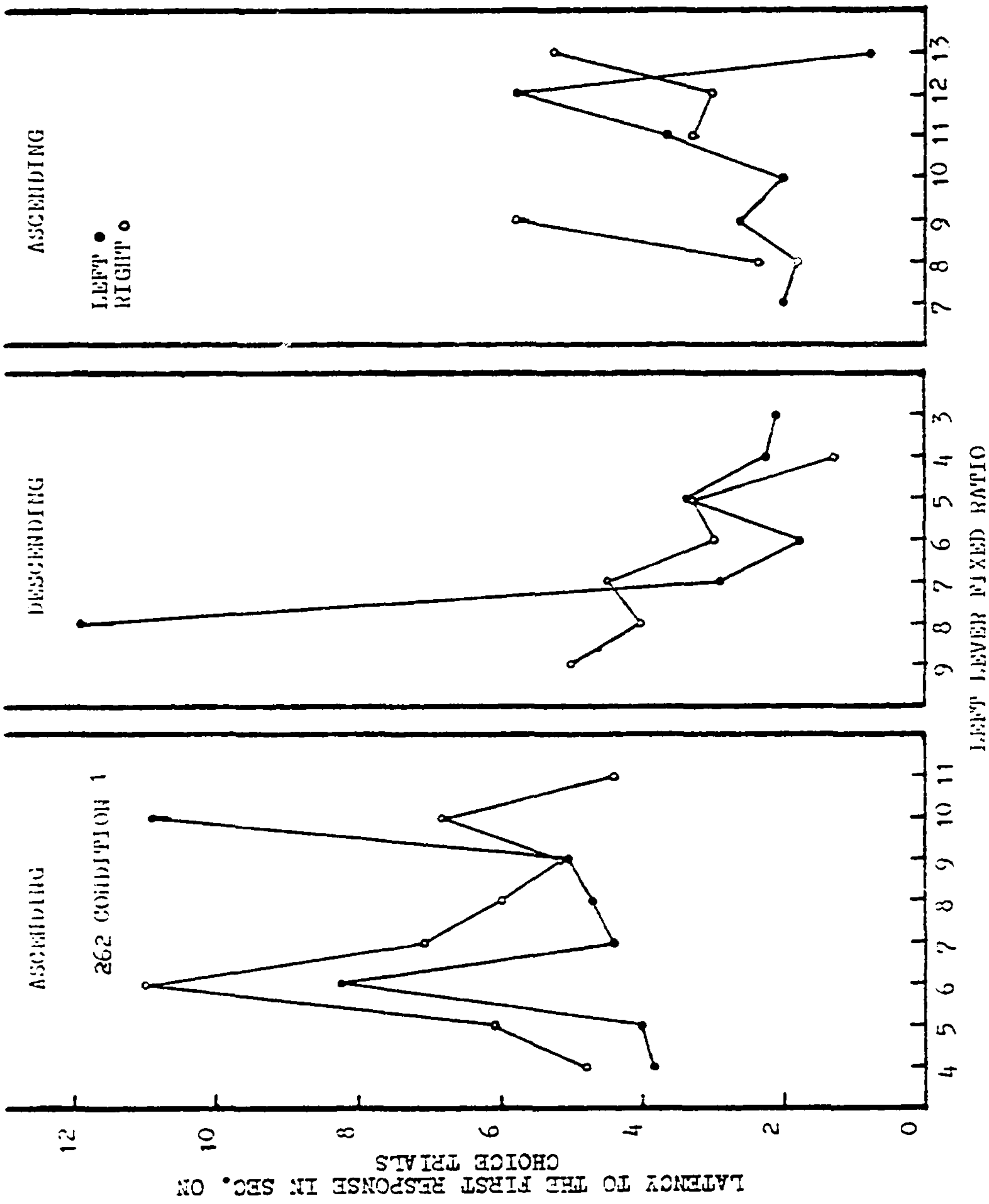
ASCENDING
262 CONDITION 1
DESCENDING
ASCENDING
LEFT ●
RIGHT ○
LATENCY TO THE FIRST RESPONSE IN SEC. ON CHOICE TRIALS
LEFT LEVER FIXED RATIO

FIGURE 5

Overall, however, there did not appear to be any clear orderly relation between changes in the left lever ratio and latency length on single-alternative or choice trials for Rat 262 in Condition I.

Averaged choice proportions for the left lever during Condition I are plotted against the left lever response requirement for at 260 in Figure 6. In general, as the ratio on the left lever was increased, the proportion of choices for the left lever decreased, but not without readily observable variability between sessions at different left lever ratios. During the series of sessions in which the ratio requirement was decreased (second panel of the figure), a switch from exclusive right lever preference to exclusive left lever preference on choice trials was not observed even when the left lever was FR 1 and the right lever was FR 5. When the left lever was changed to FR 2 (third panel) a left lever choice proportion of 0.5 was seen. At FR 4, near exclusive preference for the right lever was observed even though the ratio on the right lever was FR 5.

The average proportion of left lever choices at the various left lever ratio values in Condition I are presented in Figures 7, 8, and 9 for Rats 261, 266, and 267, respectively. For each subject in Condition I, the relationship between left lever choice proportions and the left lever ratio was similar to that described for Rats 262 and 260. For each rat, except 262, exclusive

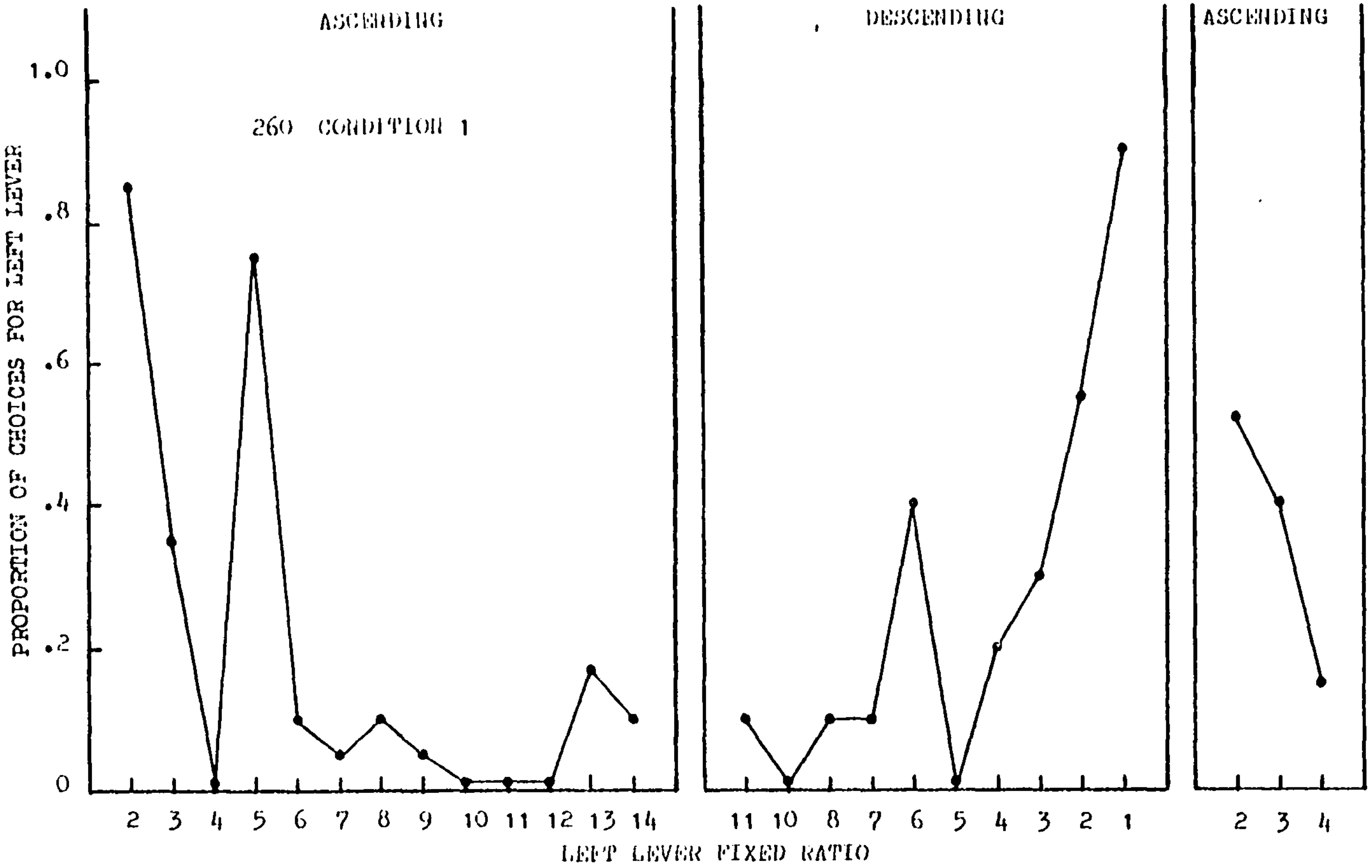
ASCENDING
DESCENDING
ASCENDING
260 CONDITION 1
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0
2 3 4 5 6 7 8 9 10 11 12 13 14
11 10 8 7 6 5 4 3 2 1
2 3 4
LEFT LEVER FIXED RATIO

FIGURE 6

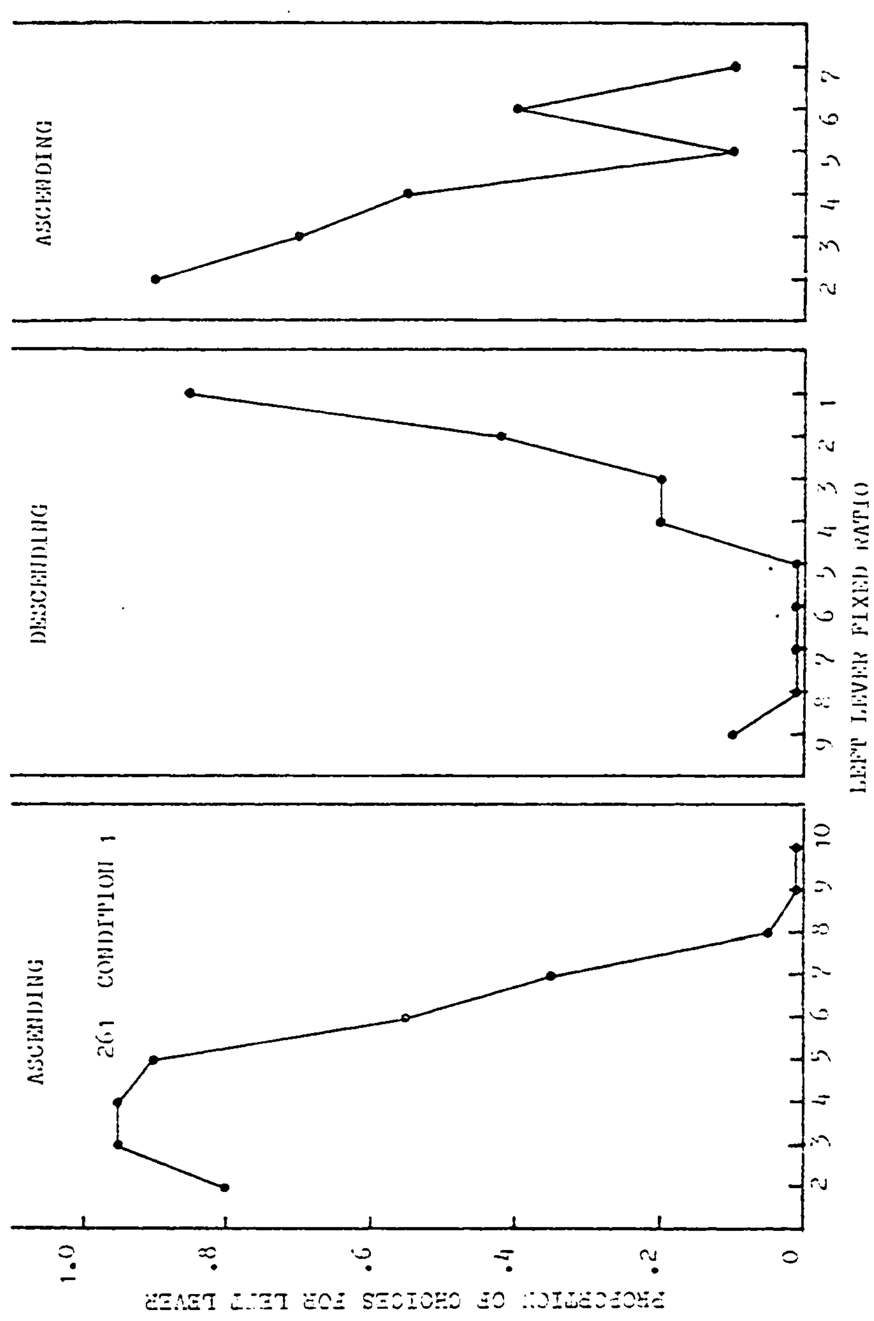
ASCENDING
261 CONDITION 1
DESCENDING
ASCENDING
1.0
.8
.6
.4
.2
0
PROPORTION OF CHOICES FOR LEFT LEVER
2 3 4 5 6 7 8 9 10
9 8 7 6 5 4 3 2 1
2 3 4 5 6 7
LEFT LEVER FIXED RATIO

FIGURE 7

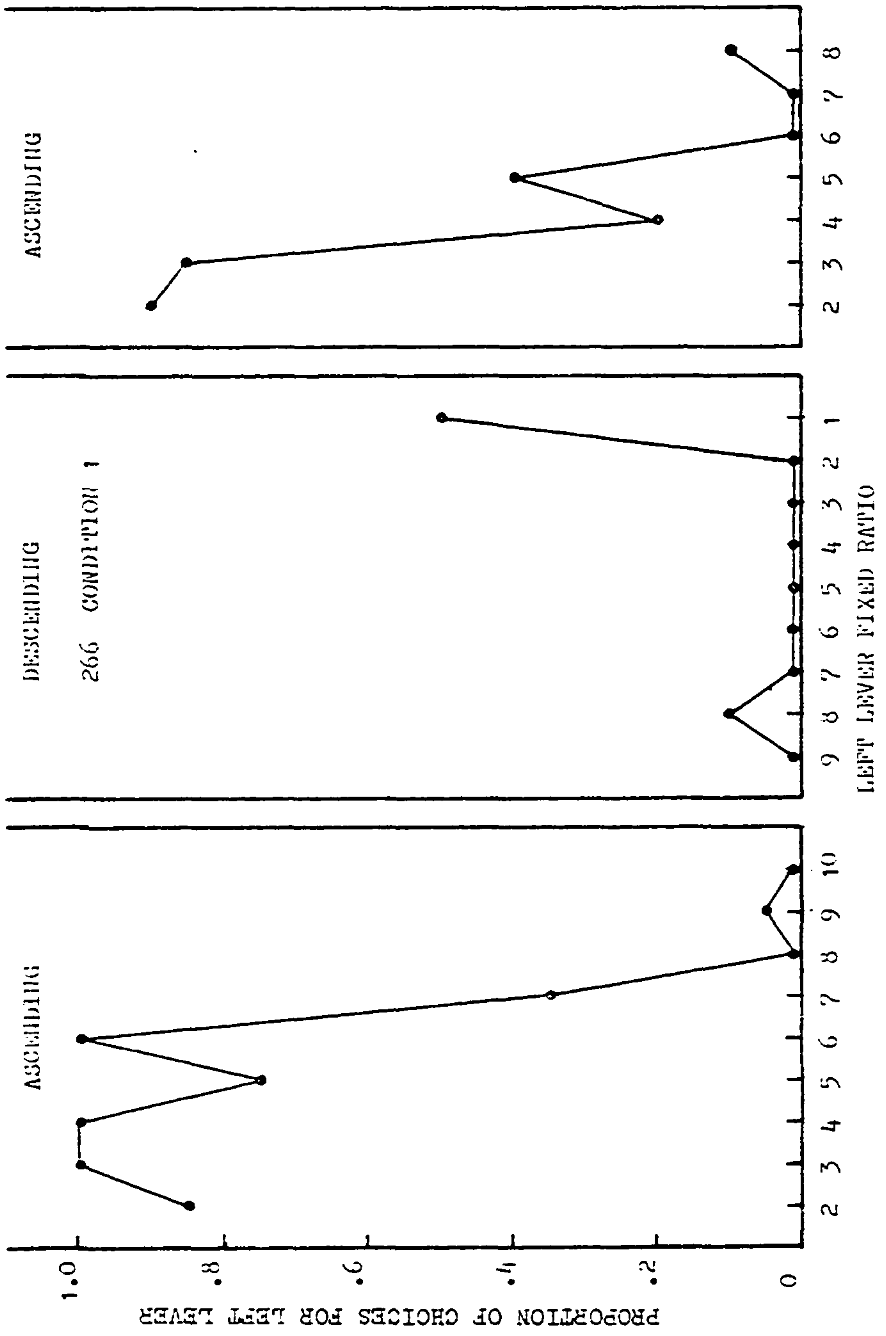
ASCENDING
DESCENDING
266 CONDITION 1
ASCENDING
LEFT LEVER FIXED RATIO
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0

FIGURE 8

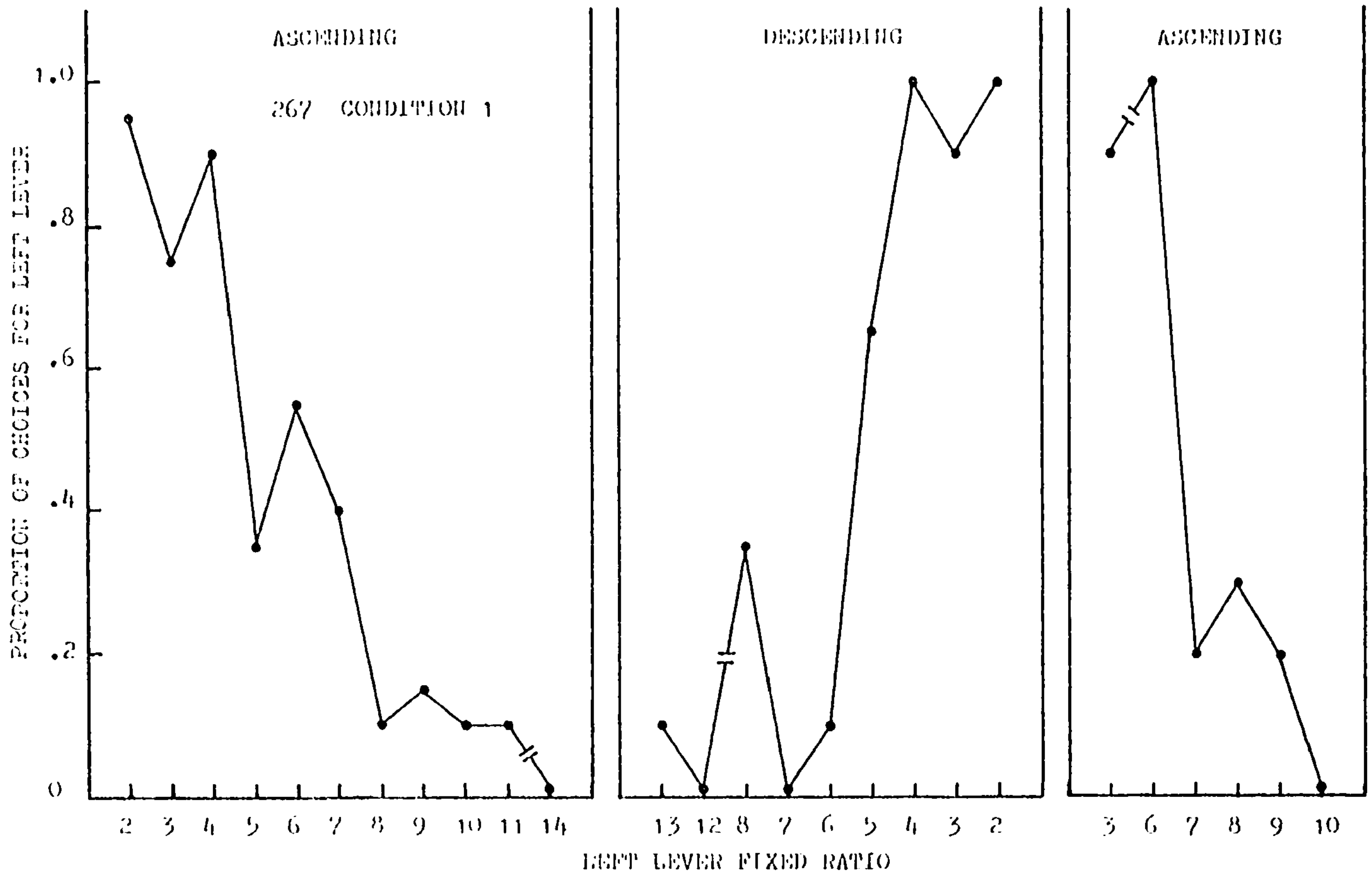
ASCENDING
267 CONDITION 1
DESCENDING
ASCENDING
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0
2 3 4 5 6 7 8 9 10 11 14
13 12 8 7 6 5 4 3 2
3 6 7 8 9 10
LEFT LEVER FIXED RATIO

FIGURE 9

preference for the right lever was observed when the left lever FR was increased to FR 8. Exclusive preference for the left lever was usually not reestablished for any rat until the ratio on the left lever was reduced to FR 2 or FR 1. The subjects were also similar in regard to the amount of increase in the left lever FR necessary in order to result in a second switch of preference from left to right levers on choice trials. The change to right lever preference, during the second series of ascending ratios, usually occurred at a ratio value lower than that observed during the first series of left lever ratio increases.

The second condition of the study was a systematic replication of the first condition. The principal change was that the response requirement on the right lever was increased from FR 5 to FR 10. Changes in the criteria from increasing the ratio on the left lever were described earlier.

In general, the results obtained in the second condition were similar to those obtained during the first condition of the study. The proportion of choices for the left lever decreased across sessions as the ratio on the left lever increased and increased across sessions when the ratio on the left lever was decreased. The data presented in Figures 10 and 11 for Rats 266 and 267, respectively, were most representative in this regard.

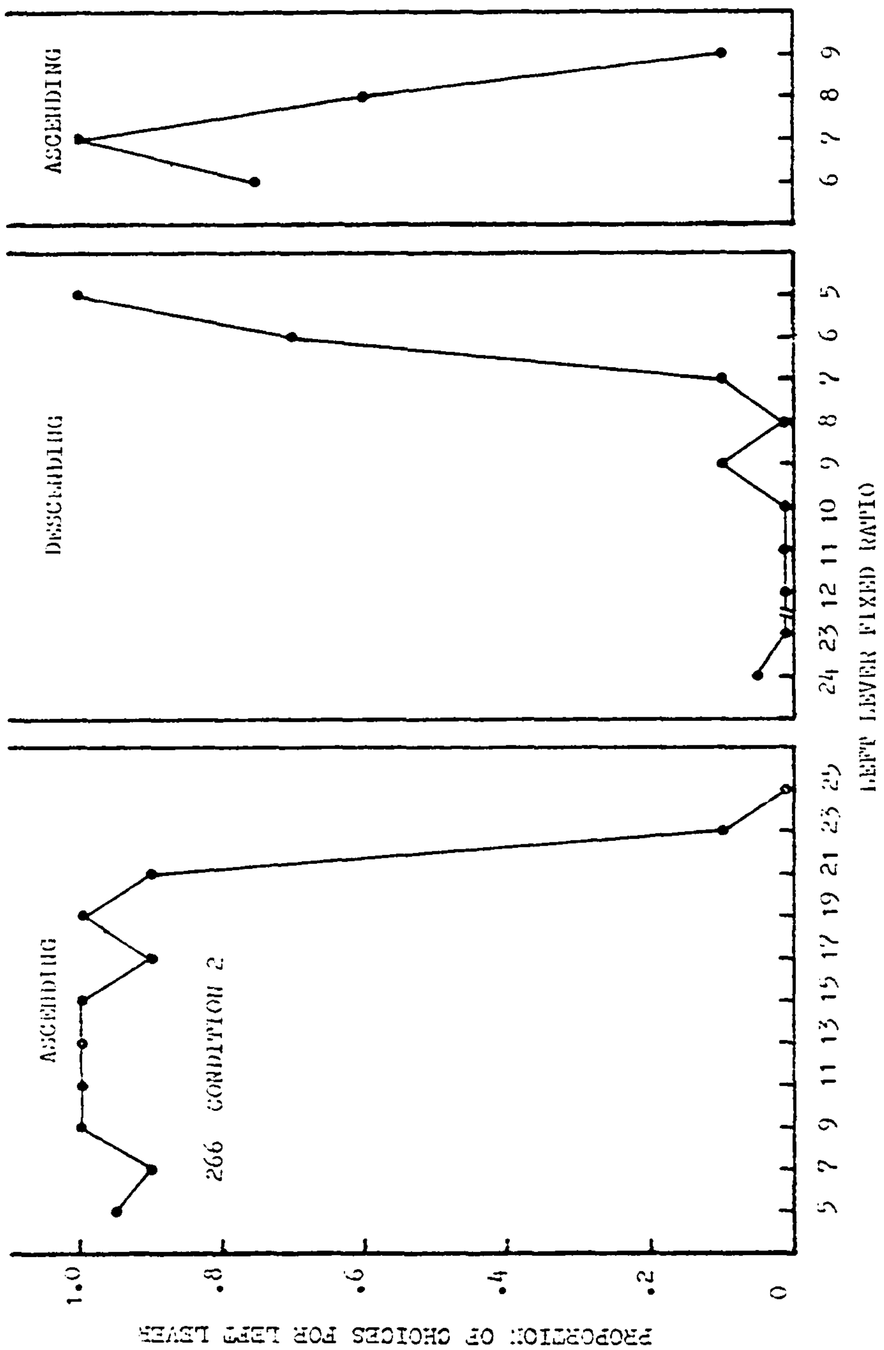
ASCENDING
266 CONDITION 2
DESCENDING
ASCENDING
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0
5 7 9 11 13 15 17 19 21 23 25
24 23 12 11 10 9 8 7 6 5
6 7 8 9
LEFT LEVER FIXED RATIO

FIGURE 10

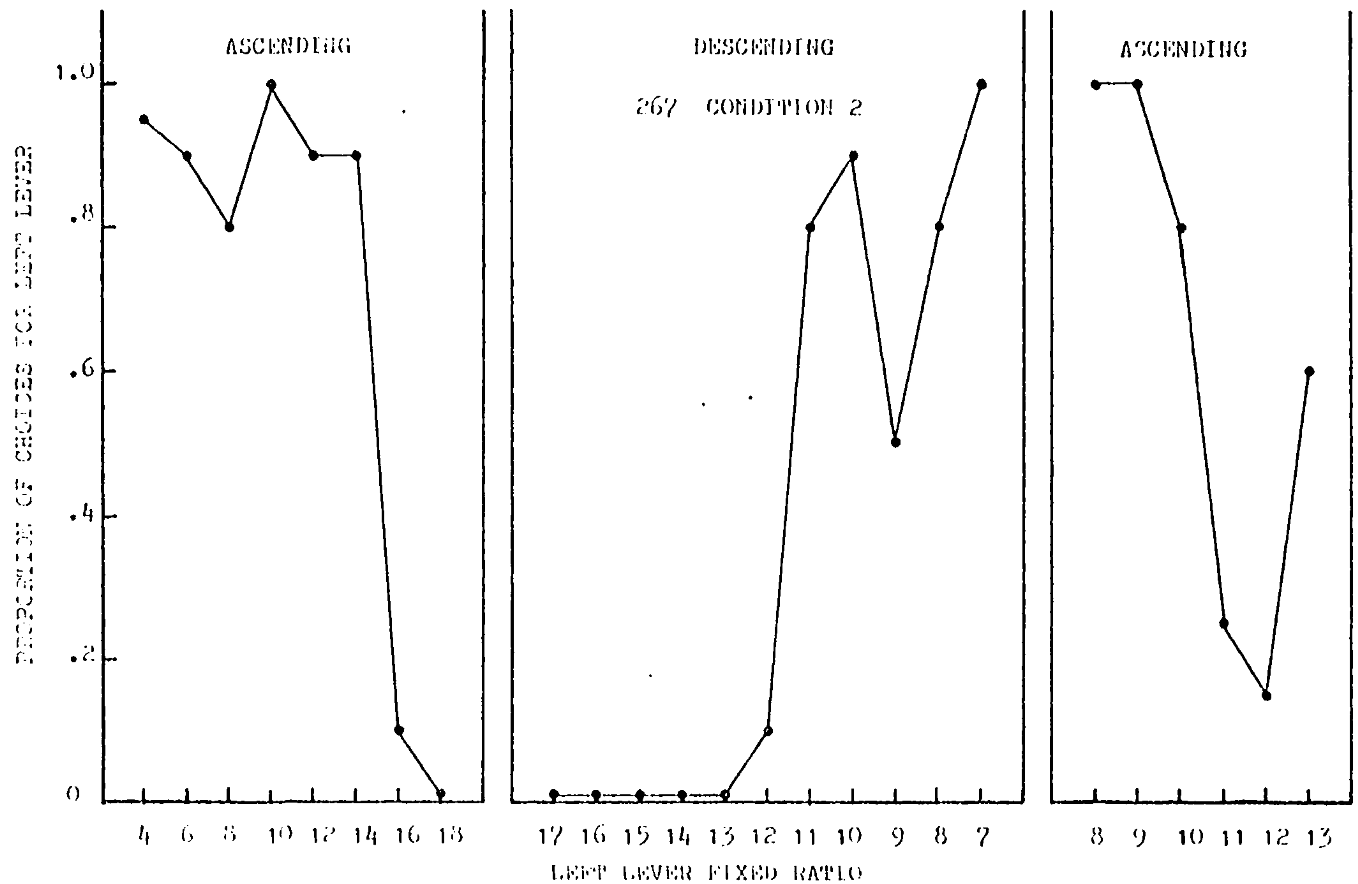
ASCENDING
DESCENDING
267 CONDITION 2
ASCENDING
1.0
.8
.6
.4
.2
0
4 6 8 10 12 14 16 18
17 16 15 14 13 12 11 10 9 8 7
8 9 10 11 12 13
LEFT LEVER FIXED RATIO

FIGURE 11

The figures plot the averaged proportion of choices for the left lever on choice trials as a function of the ratio on the left response lever. The ratio on the left lever was increased by two, across sessions, from an initial FR 5 to FR 21 before a break in exclusive preference for the left lever was observed for 266. At FR 23 preference for the left lever on choice trials decreased to 0.1, exclusive preference for the right lever. An additional session at FR 25 resulted in 10 choices for the right lever. When the left lever was then decreased across sessions, exclusive preference for the right lever was observed at each ratio down to FR 7, which was three responses less than that required to produce reinforcement on the right lever. Exclusive preference for the left lever was again observed when the left lever ratio was reduced to FR 5. The data obtained during the second series of sessions in which the left lever response requirement was increased did not replicate the findings from the first series of similar increases. During the first such series, exclusive preference for the left lever on choice trials was observed up to a left lever ratio of FR 21. During the second series, exclusive preference for the right lever on choice trials occurred when the left lever was FR 9, a difference of 11 responses.

The ratio on the left lever was increased to FR 14 before Rat 267 displayed less than an averaged left lever choice proportion of 0.8. At FR 16 preference switched completely from the left lever to the right lever on choice trials. During the series of sessions in which the ratio on the left lever was decreased, exclusive preference for the right lever was seen until the left lever was FR 11. Exclusive left lever preference was not observed until the ratio on the left lever was reduced to FR 7. The third panel of Figure 11 shows that Rat 267 did not complete the second condition of the study. During that series of sessions, a decline in the proportion of choices for the left lever was observed at lower left lever ratios, FR 10, FR 11 and FR 12, than had been recorded earlier. Rat 267 died shortly after stability of responding was obtained at FR 13.

Figure 12 shows average choice proportions for Rat 261 in the second condition. With the exception of proportion of choices for the left lever at FR 8, the initial series of ratio increases on the left lever resulted in a distribution of choice proportions similar to those observed for Rats 266 and 267. Exclusive preference for the left lever on choice trials was observed until the response requirement on the left lever was FR 12. At FR 16, the proportion of choices for the left lever had decreased to 0.0. Unlike Rats 266 and 267, the transition of lever preference from right to left levers was more gradual for 261. Exclusive right lever preference was

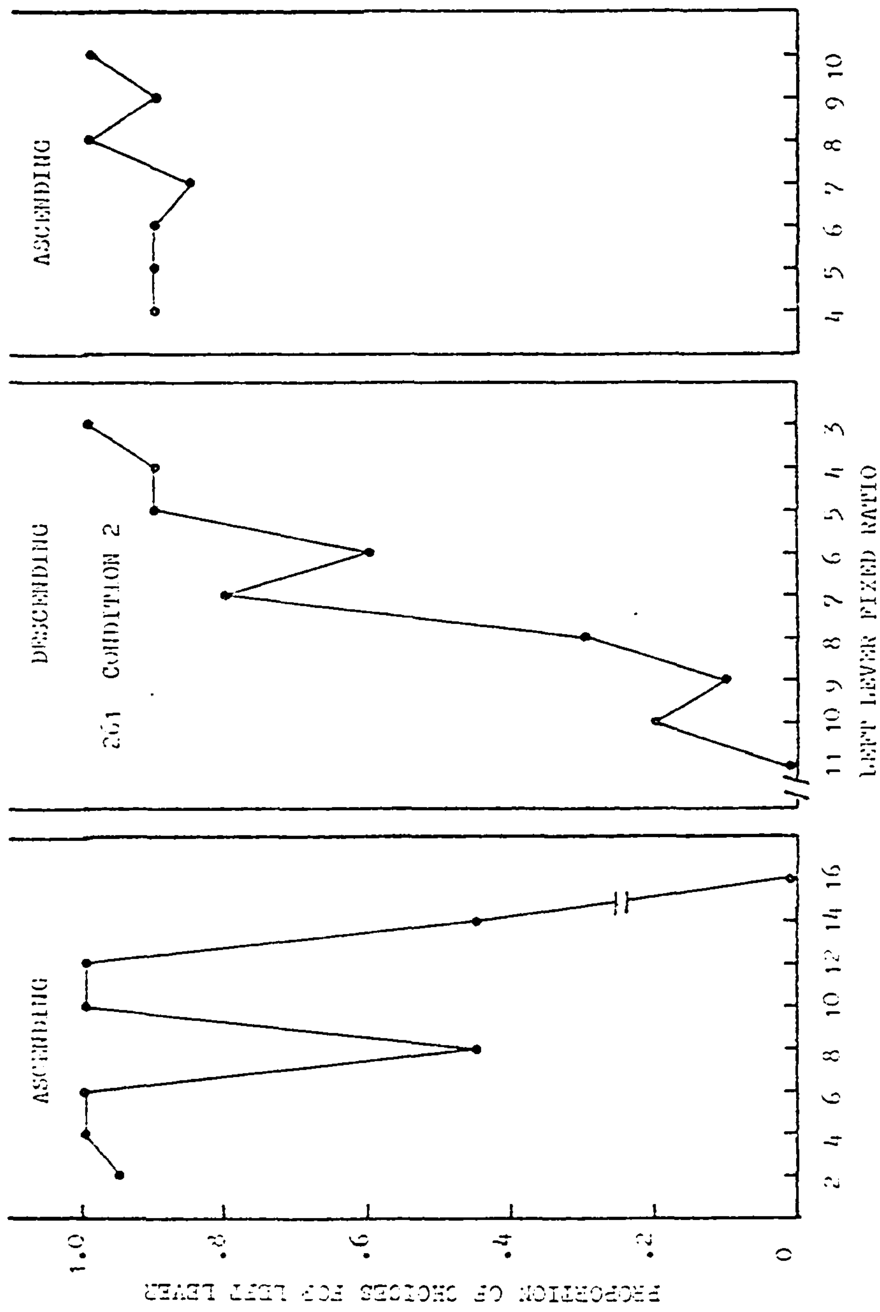
ASCENDING
DESCENDING
2:1 CONDITION 2
ASCENDING
LEFT LEVER FIXED RATIO
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0
2 4 6 8 10 12 14 16
11 10 9 8 7 6 5 4 3
4 5 6 7 8 9 10

FIGURE 12

observed until the left lever ratio was FR 11. The increase in left lever preference occurred gradually as the ratio was decreased from FR 10 to FR 3. The third panel of Figure 12 shows that a return to exclusive right lever preference was not obtained for Rat 261. The left lever ratio was increased to FR 10 and the proportion of choices for the left lever did not decrease below 0.80. The second condition was not completed as the rat apparently developed an inner ear infection and could not continue.

The choice proportion data presented in Figure 13 for Rat 260 show that exclusive preference for the left lever was not observed after the left lever response requirement exceeded FR 4. Interestingly, exclusive preference for the right lever on choice trials was observed when the response requirement on the left lever was still two responses less, FR 8, than required to produce reinforcement on the right lever. At FR 10, the averaged proportion of choices for the left lever increased to 0.40, but from FR 12 through FR 18 and down again to FR 12 the proportion of choices for the left lever was always 0.1 or less. Preference for the right lever began to decrease at FR 11 in a near linear manner to FR 7 at which point exclusive left lever preference was again obtained. The second transition from exclusive left to right lever preference was much more abrupt for

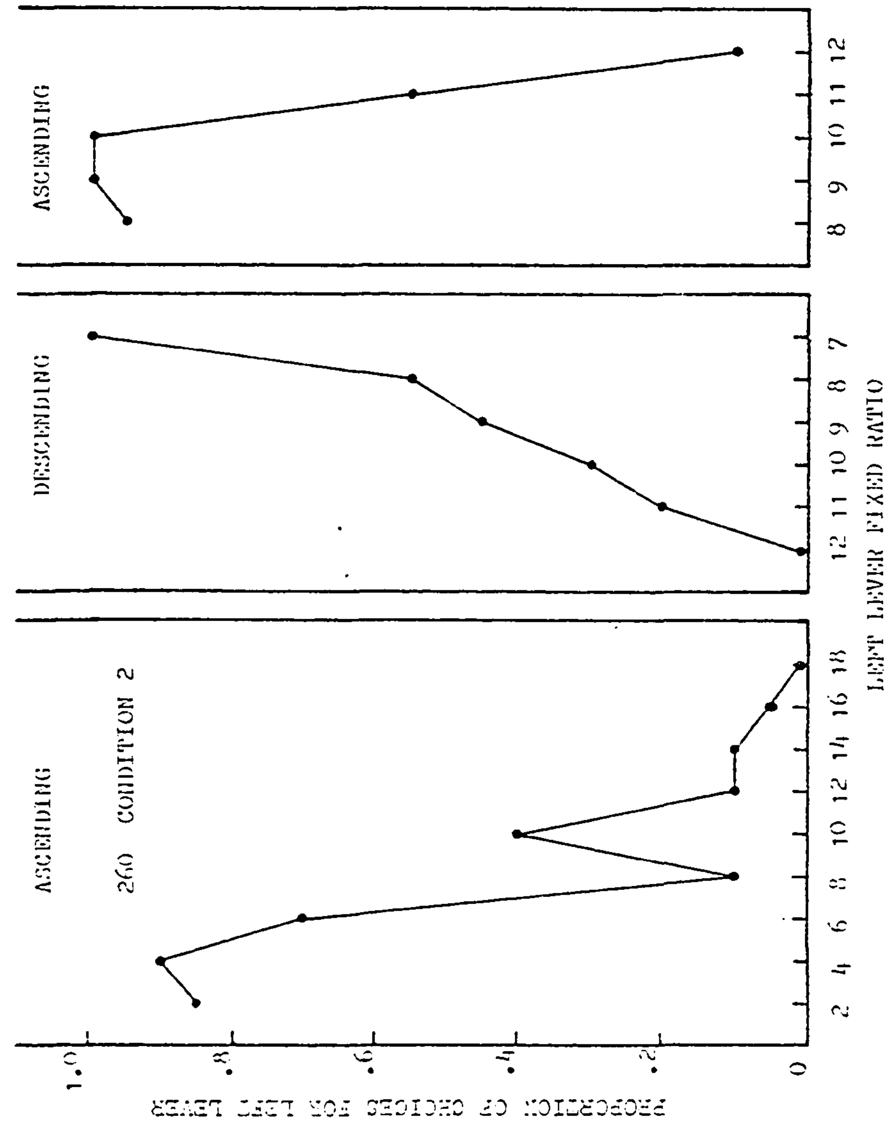
ASCENDING
260 CONDITION 2
DESCENDING
ASCENDING
1.0
.8
.6
.4
.2
0
2 4 6 8 10 12 14 16 18
12 11 10 9 8 7
8 9 10 11 12
LEFT LEVER FIXED RATIO

FIGURE 13

Rat 260. From FR 8 to FR 10, exclusive left lever preference was maintained, at FR 11 an averaged left lever choice proportion near 0.50 was obtained. At FR 12 left lever preference was 0.1, as in the initial series.

The averaged proportion of choices for the left lever across the various left lever ratio values are presented in Figure 14 for Rat 262. The response requirement on the left lever was initially FR 7. It was necessary to increase the ratio to FR 15 before exclusive left lever preference on choice trials was no longer observed. An increase to FR 35 was required before the right lever was preferred exclusively on the choice trials. The distribution of choice proportions at the intermediate ratios were variable; each left lever ratio increase was not always accompanied by a subsequent decrease in the proportion of choices for the left lever. It should be noted that no other subject required such a large increase in response requirement in order to produce a switch from left to right lever preference. After the response requirement on the left lever was increased to FR 35, Rat 262 required several sessions in order to meet the stability requirement for decreasing the ratio. This was due to the fact that the subject failed to respond on a large proportion of the choice trials and single-alternative trials. Figures 15 and 16 show the mean number of single-alternative and choice trials without a

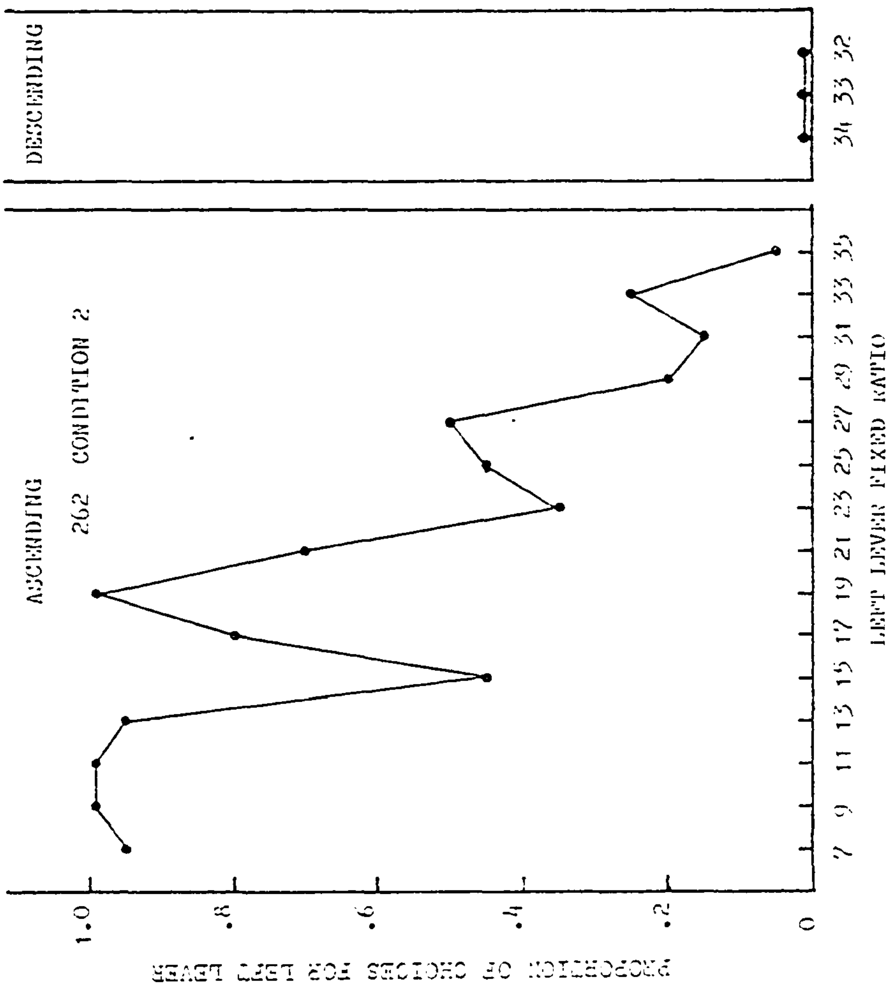
ASCENDING
262 CONDITION 2
DESCENDING
PROPORTION OF CHOICES FOR LEFT LEVER
1.0
.8
.6
.4
.2
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
34 33 32
LEFT LEVER FIXED RATIO

FIGURE 14

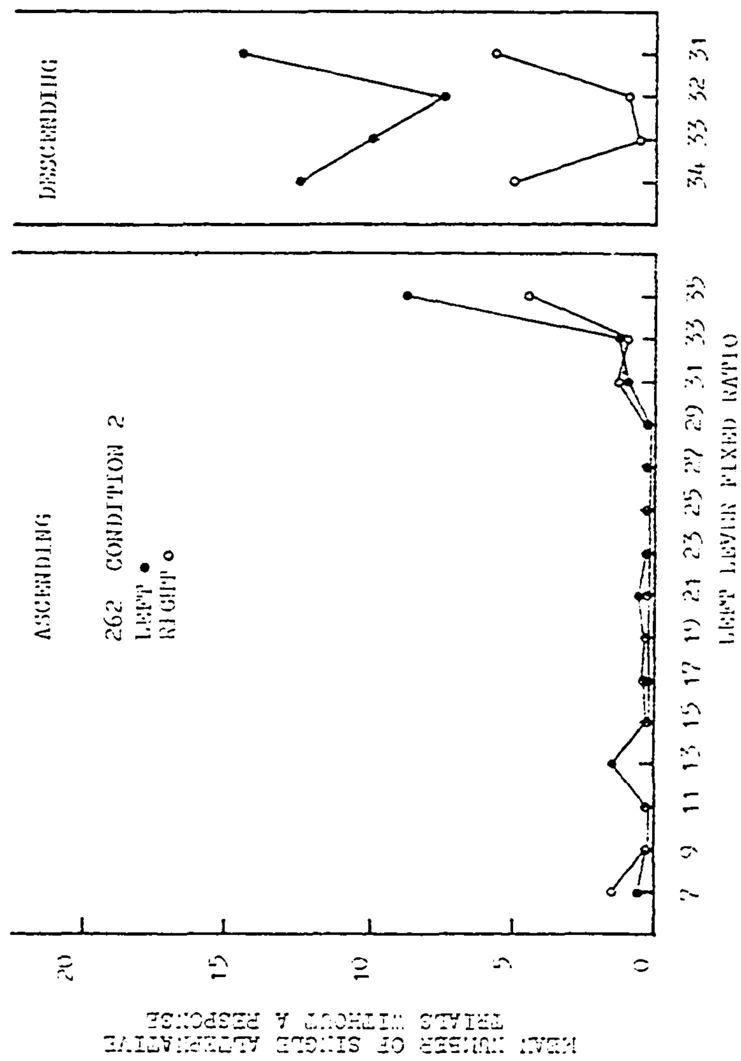
ASCENDING
DESCENDING
262 CONDITION 2
LEFT ●
RIGHT ○
MEAN NUMBER OF SINGLE ALTERNATIVE TRIALS WITHOUT A RESPONSE
LEFT LEVER FIXED RATIO
0
5
10
15
20
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
34 33 32 31

FIGURE 15

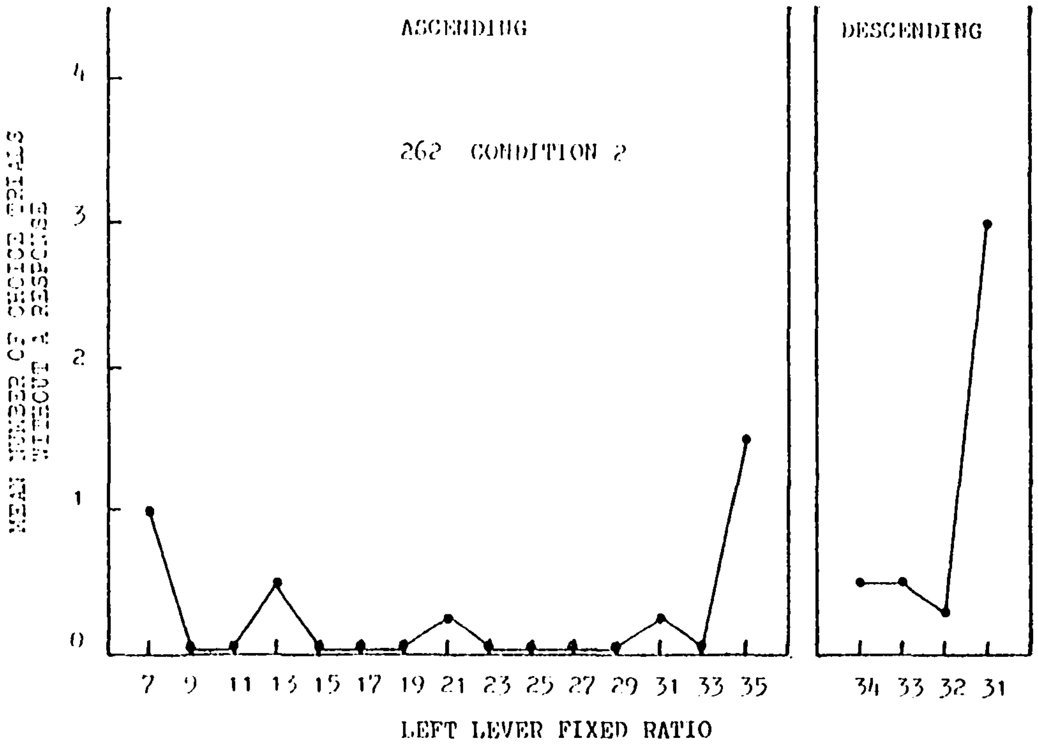
ASCENDING
DESCENDING
262 CONDITION 2
MEAN NUMBER OF CHOICE TRIALS WITHOUT A RESPONSE
0
1
2
3
4
7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
34 33 32 31
LEFT LEVER FIXED RATIO

FIGURE 16

response as a function of the left lever response requirement for Rat 262. As can be seen in Figure 15, at FR 35 an average of nearly nine left lever single-alternative trials timed out per session. The mean number of right lever single-alternative trials without a response was less than five. Figure 16 shows that, on the average, more than one choice trial per session went without any response at FR 35. The mean number of choice trials without a response decreased at FR 34 through FR 32 but increased to an average of three at FR 31. The mean number of left and right lever single-alternative trials without a response increased at FR 31 to approximately 15 and five trials per session, respectively. At that point the second condition was terminated for Rat 262.

In summary, the results from the first and second conditions of the study showed an orderly relation between the response requirement on the left lever and the proportion of choices for the left lever on choice trials. The latencies presented for Rat 262 in the first condition did not reveal any consistent relation to the response requirement on the left lever. As would be expected, when the right lever was changed to FR 10 during the second condition the amount of increase in the left lever ratio required in order to change preference from left to right levers was greater than that required to produce the same change in the first condition. In general, it was found that the transitions in preference from left to right or right to left levers on choice trials did not reliably occur at the same left lever ratios.

DISCUSSION

The results of the present study showed that preference for reinforcement alternatives in a discrete-trial choice procedure was affected by the response requirement associated with each alternative. In other words, given an equal amount of reinforcement for responding on either alternative, preference on choice trials depended in large part on the number of responses required to produce the reinforcement associated with an alternative in relation to the number of responses required to produce reinforcement on the other alternative.

The procedure used in the present study made a number of comparisons of the effects of the independent variable possible. Each condition of the study allowed within- and between-subject comparisions of the effects of the left lever ratio requirement on the proportion of choices for the left lever on choice trials. Such comparisons were always made across sessions at the various ratio values. It was also possible to compare the effects of changes in the left lever response requirement on left lever choice proportions between conditions of the study, which differed in regard to the right lever response requirement.

While the general finding of the study was replicated within and between subjects across the two conditions, it should be noted that the subjects differed in regard to the left lever ratio values at which exclusive preference for either lever was obtained and in the proportion of choices for the left lever exhibited at the intermediate left lever ratio values. The differences were observed both within and between subjects. Rarely was the same proportion of choices for the left lever observed after each presentation of a given left lever ratio. For instance, Figure 3 shows that Rat 262's proportion of choices for the left lever at FR 7 (FR 5 on the right) was 0.65 during the initial series of sessions in which the left lever ratio was increased. During the next series of sessions where the ratio on the left lever was decreased, the proportion of choices for the left lever was 0.15 at FR 7. During the final series of sessions, in the first condition, the proportion of choices for the left lever was 1.0 at FR 7.

There are several factors which may have contributed to the difficulty to replicate with precision the proportion of choices for the left lever at a given ratio and each subsequent presentation of that ratio value. One possibility concerns the criteria for increasing or decreasing the ratio on the left lever. When exclusive preference was obtained at any left lever ratio, the ratio was increased (or decreased) the following session. At less than exclusive preference, a minimum of two sessions were required in order to meet the stability criteria.

This resulted in more exposure, as defined by number of trials, to the contingencies of reinforcement associated with the left and right levers. Assuming that the differential control over responding exerted by the left and right levers on choice trials increased as a function of such exposure, one would expect a difference between the choice proportion obtained after one session at a given ratio compared to that obtained after several session's exposure to the same left lever ratio, particularly if the difference between the left and right lever response requirements was not large.

Another possibility concerns the manner in which the left lever response requirement was changed between sessions. The one or two unit change in the ratio on the left lever between sessions may not have produced a sufficient difference in the left and right lever response requirements to result in a very precise differential control of responding on choice trials, particularly when the ratios on the left and right levers were similar. This possibility does not seem particularly convincing, however, especially in regard to the first condition of the study where the right lever response requirement was FR 5.

A third factor which may have affected the precision with which the results were replicated involves the recent history of responding on choice trials. Several rats showed a tendency to prefer a lever exclusively on choice trials even though the response requirement on that lever was greater than that on the other lever. Examples are Rat 266 in the first condition and Rats 266 and 267 in the second condition. When these subjects switched from exclusive left to right lever preference in the first ascending series of ratios, the change occurred quickly. The proportion of choices for the left lever appeared to lag behind increases in the ratio on the left lever. Such an effect has been called hysteresis and may be explained by assuming that in the recent histories of the subjects the left lever was associated with more reinforcement than the right lever due to the smaller ratio on the left lever. Given such differential reinforcement for responding on the left lever, it is not unlikely that the subjects would continue to respond on the left lever during future choice trials, which would result in the left lever being increased even more. Eventually, the difference in reinforcement associated with each lever was large enough to produce a quick change in lever preference.

The latency data presented for Rat 262 in the first condition were quite variable. As was seen in Tables I and II, the latencies tended to become longer as the session progressed. This tendency may have been partly due to satiation and/or fatigue as the session progressed.

Another consideration in this regard is that each ITI was of variable length. Following reinforcement on any given trial, the subjects frequently groomed or changed positions in the chamber. Such behaviors would have increased the latency to respond on a trial if the subject were not in an optimal position at the beginning of the next trial. The between session latencies were quite possibly affected by changes in the degree of water deprivation which could not always be controlled with precision.

The results of the second condition of the study replicated in form the results of the first condition. For at least three subjects, 261, 266 and 267, a greater difference between left and right lever response requirements was necessary to produce a complete switch in preference than was required in the first condition. Such a finding was not unexpected. Since the right lever was FR 10 during the second condition, it seems likely that a larger difference between left and right lever ratios was necessary in order to result in differential control of responding by the contingencies associated with a lever.

The results from Rat 262 during the second condition were not easily accounted for. Given a right lever response requirement of FR 10, it was necessary to increase the ratio on the left lever to FR 35 before exclusive preference for the right lever on choice trials was observed. That the subject continued to respond at all on the left lever at ratios above FR 30 was surprising given the relatively small amount of water reinforcement produced. It is possible that the procedure "shaped" responding to occur at such high ratios. The increase in the left lever response requirement from FR 7 to FR 35 occurred over many sessions and the relative increase between sessions became smaller and smaller as high ratios were programmed (Uzunoz, 1979).

Even if the above analysis could account for the fact that left lever responding was maintained at high ratios, it does not explain why a switch in preference was not observed at lower ratios. One possibility is that there was a strong left side bias for Rat 262. The procedure did not control for side bias by alternating the location of the lights, tones, and ratios; nonetheless, it remains a puzzlement as to why such a large difference in ratios was necessary before a switch in lever preference occurred. Once the switch in preference did occur, it appeared that the amount of reinforcement produced was no longer sufficient to maintain responding with any consistency.

The procedure was not without difficulties. A major point of concern was the number of sessions required to complete a condition. An attempt was made at the beginning of the second condition to hasten the acquisition of data by modifying the stability criteria and by increasing the amount by which the left lever ratio was increased. Those changes made it possible to complete the initial series of sessions in the second condition sooner, but not by a large amount.

There are several ways in which the procedure could possibly be made more efficient. One way would be to simply run only two sessions at each left lever ratio. If that were done in addition to adding another choice trial at the end of each five trial block, the equivalent of the two sessions' data, in terms of the number of choice trials, would be acquired in one session. Two sessions on such a modified procedure would generate the equivalent of four sessions' data from the present procedure. Rarely was it necessary to run more than four sessions at a ratio value before stability was attained.

Another approach would be to model more directly Johanson's 1971 procedure described earlier. That procedure presented reinforcement alternatives in separate blocks and controlled for the effects of side bias by randomizing the location of alternatives. Choice trials were also presented as a single block of trials and the location of each alternative was randomized within the block. The supposed benefits of such procedural modifications, particularly in regard to the speed with which data are acquired, await empirical confirmation. A more efficient procedure would be desirable only if orderly relations in the data were also obtained.

In conclusion, the results of the present study show that preference for one of two reinforcement alternatives varied as a function of the response requirement associated with one of the alternatives. Given this finding and the fact that the subjects were easily trained to respond on the procedure, it would seem that the discrete-trial choice procedure presented here holds promise for future research investigating a number of behavioral phenomena. Particularly important in this regard is Snapper's (1979) observation that for the science of behavior to become a true science it must eventually be in a position to make quantitiative statements regarding the relative value of reinforcements differing in quantity, as well as quality. The procedure presented here appears to be a step in that direction. Future research utilizing this or a similar procedure could profitably address such issues, provided that empirically established refinements in the procedure are made and that the generality of the procedure is confirmed with regard to different species, reinforcers, and schedules of reinforcement.

BIBLIOGRAPHY

Boivin, J. M. A comparison of choice procedures: Positive reinforcement. Unpublished Master's Thesis, Western Michigan University, 1978.

Catania, A. C. Concurrent performances: A baseline for the study of reinforcement magnitude. Journal of the Experimental Analysis of Behavior, 1963, 6, 299-300.

De la Garza, R. R. A comparison of choice procedures: Negative reinforcement. Unpublished Master's Thesis, Western Michigan University, 1978.

de Villiers, P. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of Operant Behavior, Englewood Cliffs, New Jersey: Prentice Hall Inc., 1977.

Herrnstein, R. J. Relative and absolute strength of responses as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.

Hodos, W. Progressive ratio as a measure of reward strength. Science, 1961, 134, 943-944.

Hodos, W. and Kalman, G. Effects of increment size and reinforcer volume on progressive ratio performance. Journal of the Experimental Analysis of Behavior, 1963, 6, 387-392.

Johanson, C. E. Choice of cocaine by rhesus monkeys as a function of dosage. Proceedings of the 79th Annual Convention of the American Psychological Association, 1971, 6, 751-752.

Johanson, C. E. Pharmacological and environmental variables affecting drug preference in rhesus monkeys. Pharmacology Review, 1975, 27, 343-355.

Johanson, C. E. and Schuster, C. R. A choice procedure for drug reinforcers: Cocaine and methylphenidate in the rhesus monkey. The Journal of Pharmacology and Experimental Therapeutics, 1975, 193, 676-688.

Johanson, C. E. and Schuster, C. R. The effects of electric shock on responding maintained by cocaine injections in a choice procedure in the rhesus monkey. Psychopharmacology, 1977, 53, 277-282.

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

Nevin, J. A. Response strength in multiple schedules. Journal of the Experimental Analysis of Behavior, 1974, 21, 389-408.

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

Skinner, B. F. The Behavior of Organisms: An Experimental Analysis. New York: Appleton - Century - Crofts, 1938.

Skinner, B. F. Science and Human Behavior. New York: The Free Press, 1953.

Skinner, B. F. Are theories of learning necessary? In B. F. Skinner (Ed.), Cumulative Record. New York: Appleton - Century - Crofts, 1961.

Skinner, B. F. Contingencies of reinforcement: A theoretical analysis. New York: Appleton - Century - Crofts, 1969.

Snapper, A. G. A modest proposal for a new dependent variable. Paper presented at Western Michigan University, Kalamazoo, April, 1977.

Snapper, A. G. and Inglis, J. The Super Sked Manual 3. Sked Users Group, Psychology Department, Western Michigan University, 1979.

Uzonoz, A. A parametric study of geometric progressive ratio performance. Unpublished Doctoral Dissertation, Western Michigan University, 1979.