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Temporal Dimensions of Response Duration

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TEMPORAL DIMENSIONS OF RESPONSE DURATION

by

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LIFE

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CHAPTER I

INTRODUCTION AND PURPOSE

In very recent years pharmacologists and neurochemists have looked to behavior in the hope of shedding some light on the complex actions of neurohumors and psychoactive drugs. No longer is it sufficient to know how a particular drug acts on the heart, or how a brain enzyme effects muscle contractions in vitro. Nor is it enough to record vague, general observations about the behavior of treated subjects. These disciplines need a simple, reliable, and sensitive behavioral technique to match their own chemical techniques. They have their bioassays; they now need a behavioral assay.

Fortunately, operant conditioning is able to fill this need. By selecting a simple response or bit of behavior (e.g., a press of a lever by a rat) and applying reinforcement (e.g., food) at appropriate times, it is possible to get a consistent and reproducible baseline of behavior from hour to hour, or day to day. If the schedule of reinforcement is sensitive enough, various changes in the organism's internal condition (drug states, neurohumor imbalance, etc.) should be reflected in measurable changes in its behavior.

The problem for the behavioral scientist is to develop schedules which are appropriate for the particular study being undertaken. Many schedules (e.g., simple FR) are very resistant to behavioral changes for even large

doses of some drugs. The usual behavioral measure for all these studies is the rate of response. Now that even more sensitive measures of behavior are demanded, other dimensions of the response must be thoroughly investigated.

Since the earliest days of research in operant conditioning, the characteristic measure of behavior has been the rate of response. That the operant has dimensions other than rate was no doubt realized, but only recently have these neglected dimensions come under scrutiny. Perhaps one of the most potentially valuable of these reinstated measures of behavior is response duration.

The definition of response duration is related to the equipment used in studies of operant conditioning. Since nearly all apparatus used in this type of research employs electrical circuitry, a response must close (or open) a circuit in order to be recorded and reinforced. Therefore, whether it is a pigeon pecking at a key, a rat pressing a lever, or a child matching words and pictures on a matching-to-sample unit, the relevant response is the one that closes the electrical circuit, thereby operating the recording and reinforcing apparatus. Keeping this situation in mind, response duration can be operationally defined as the length of time the electrical circuit remains closed for each response.

The present study includes two independent experiments designed to furnish additional information about response duration, so that this measure may be used eventually in developing more sensitive schedules of reinforcement.

Experiment I continues the recent studies of response duration in rats.

In any apparatus employing a lever (or bar) and microswitch combination, reinforcement can be received only when the animal presses the bar with at least the minimum force required to overcome the combined resistance of the bar and springs of the microswitch. In effect, the animal is placed on a force contingency schedule. For example, a 15 gm. force contingency schedule requires a rat to exert at least 15 gm. of force to overcome the resistance of the bar and microswitch, i.e., no bar press under 15 gm. will deliver reinforcement.

Changes in force contingency schedules may effect duration of bar depression similar to the effects of changes in other schedules of reinforcement. If D (average response duration) is to be used as a measure of behavior the possible effects of the bar force on D should be known. Since D is determined, in this case, by the amount of time the microswitch is closed by the exertion of sufficient force on the bar, D is likely related to the particular force contingency schedule under which the rat is working. For example, a rat with a D of .30 sec. on a 15 gm. bar may have a longer or shorter D on a 45 gm. bar. The present experiment, investigating the relationship between duration of response and changes in force contingency schedules, will attempt to specify more clearly the relations between these dimensions of the bar press response.

Experiment II is designed to furnish some information about human response duration, a heretofore neglected area of research. Since the development of the very complex matching-to-sample schedules, which present the human subject with a task much more worthy of his capabilities, operant conditioning techniques are being used more and more in human drug studies.

Hence, in order to develop more sensitive schedules, some study of human response duration must be attempted. In the present experiment, response duration will first be studied in a very simple task. Another task will later be introduced to determine if the response duration can be altered.

CHAPTER II

REVIEW OF THE LITERATURE

The first mention of response duration as a measure of behavior in operant conditioning was made by Skinner (1938). In analyzing the behavior of a rat trained to press a bar for water, he described response duration as one of the many dimensions of bar pressing behavior. Other dimensions included force, rate, and inter-response time. The characteristic measure of operant conditioning behavior, however, has been the rate of response. Skinner (1948) has expressed the belief that "the rate of responding appears to be the only datum that varies significantly and in the expected direction under conditions which are relevant to the learning process." In their extensive study of the effect of different schedules of reinforcement upon operant conditioning behavior, Ferster and Skinner (1957) used the rate of response exclusively as the measure of behavior.

Not until 1954 (Hurwitz) did a study appear which used duration as a measure of behavior in operant conditioning. In his study, which used albino rats in the bar pressing situation, Hurwitz found that response duration was a very sensitive measure of changes in behavior under the following conditions. Response duration was found to be subject to systematic variation during the initial period of learning, this variation decreasing with increased practice. In addition, both the absolute value of response duration and its variability

increased during extinction. In general, there was found to be an increased stereotopy of response duration during regular reinforcement and increased variability during extinction. These results led Hurwitz to conclude that "... Skinner's claims are excessive ..." Both the rate of response and the total response output made within a selected period of observation were found to be very rough guides to the changes in behavior occurring during extinction and to the changes which had occurred throughout the learning period.

The importance of the other dimensions of the operant, in addition to response rate, is now being recognized. Gilbert (1958) pointed out that it is possible to list seven dimensional properties of the operant. In these fundamental dimensions he included latency, tempo, perseveration, duration, intension, extension, and direction. The dimensions he listed were said to be fundamental in the sense that other operations of behavior measurement could be reduced to these seven and the seven could not be further reduced. Empirical characteristics of several of these dimensions were discussed and particular reference was made to the pitfalls of uncritically combining the dimensions. Gilbert also felt that response rate and response output are not always the most sensitive measures of behavior. In a recent book, reflecting the latest trends in operant conditioning, Sidman (1960) recognizes the fact that the rate of response is not the only important dimension of the operant. He mentions that latency, duration, and force may also be used as valuable measures of behavior.

The force dimension of the bar press has also recently come under scrutiny. Trotter (1956a; 1956b) found that the force exerted on the bar was a far more adequate measure in the study of reactive inhibition, than was

the number of bar depressions. Force was found to have similar demensional properties to duration of response during regular reinforcement and extinction (Notterman, 1959). Notterman gave a detailed description of the emission of force by rats during acquisition and extinction of bar pressing responses. He was able to show that the distribution of forces (exerted in pressing the bar) emitted during acquisition peaked at a value approximately twice that of the force required for reinforcement, and that both magnitude and variability of force decreased during acquisition and increased during extinction.

An ingenious experiment, studying the general variability of responses, was undertaken by Antonitis (1951). Twelve male albino rats were trained to run from a starting-feeding compartment to a 50 cm. response slot, insert the nose in the slot, and return to the compartment to receive food reinforcement. The variability of nose position was determined for each rat in terms of the mean variation of the response from the median position. Over 6,600 photographs of nose-thrusting responses were analysed to determine response variability during unconditioned responding, extended regular conditioning, extinction, and reconditioning. Variability was found to be consistently greater at the beginning than at the end of the conditioning and reconditioning sessions. In addition, it was shown that the variability was relatively high and followed no regular trend during unconditioned responding and extinction periods, in contrast to the low variability found during the conditioning and reconditioning sessions.

Trotter (1957) has divided the bar pressing situation into three temporal components: the active time when the rat is touching the bar; the

eating time spent in eating and picking up the food or water; and extra time spent in washing, resting, etc. With a well trained rat, active time and extra time are small, and eating time mainly determines the rate of reward delivery. Active time was found to be affected by a change of the weight on the bar, the time between reward deliveries is affected by the amount of reward, and the extra time is affected by extinction conditions. In general, Trotter found results similar to those of Hurwitz, in that increases in D (average response duration) from low values in extinction to high values in extinction were found to be a continuous process, with longer durations more common as extinction proceeded.

One of the earliest intensive studies of bar press response duration was that performed by Schaefer and Steinhorst (1959). In this study, great care was taken in designing the apparatus, so that the rat was able to set its own rate and duration of response. It was found that D differentiated among animals, but within one animal it was a relatively stable measure, rarely varying more than .10 seconds under regular reinforcement. Changes in schedules of reinforcement (as from continuous reinforcement to reinforcement for every fifth response) were followed by a significant increase in D, with a return to normal after the new schedule had been in effect for several experimental sessions. It was also demonstrated that changes in some schedules of reinforcement are not immediately followed by a change in the rate of response, whereas they are represented by immediate changes in response duration.

Schaefer (1959) has also presented evidence to indicate that mild stress has no significant effect on the D of adult rats, but that rats which have

received stress early in life have a higher D when they are adults, than
a control group which had received no stress. In a later study, Schaefer
(1960a) was able to show that small differences in the levers or bars of the
apparatus are reflected in changes in the normal D of the rats. An attempt
has been made to decrease the normal D of one rat by reinforcing response
durations which are less than the normal D (Schaefer, 1960b). The normal D,
which was found to be .28 sec., was not significantly changed, however, even
after over 30 days of schedules which reinforced the animal for durations as
short as .15 sec.

A number of recent studies have added to the general body of information
about D in the albino rat. Millenson and Hurwitz (1961) examined variations
in response durations and successive runs of responses made by three rats in
a lever pressing apparatus during continuous reinforcement and a subsequent
extinction session. Extinction seemed to produce an increase in dispersion
and the central tendency of the response durations, which had previously
stabilized during continuous reinforcement in approximately symmetrical dis-
tributions. Under continuous reinforcement the average response duration was
.18 sec., whereas during extinction it was .84 seconds. They concluded that
behavioral measures, such as response duration, would supplement frequency
of response as a convenient index of behavior variation, and thus aid in a
more complete description of behavior under different experimental conditions.

Margulies (1961) has received results that are very similar to those of
Hurwitz. Response durations for 30 rats were obtained for operant level re-
sponding, regular reinforcement, and extinction. The results demonstrated
that the response duration was high in the operant level, declined to an

asymptote in regular reinforcement, and again reached high values late in extinction. Response duration distributions found early in extinction were similar to those obtained late in conditioning, whereas, distributions obtained late in extinction more closely resembled those obtained in the operant level.

In the latest published study in their series, Millenson, Hurwitz, and Nixon (1961) investigated the bar pressing behavior of 12 hooded rats using milk reinforcement. They found that when the rats were changed to fixed interval reinforcement schedules from a continuous reinforcement training schedule, the central tendency and dispersion of the response durations remained two to three times higher than the corresponding values obtained under continuous reinforcement. In addition, under a fixed ratio schedule, where the rat receives reinforcement for every fifth response, asymmetrical duration distributions are obtained, which show a narrow dispersion and low median. Finally, it was found that for many schedules of reinforcement there was no consistent change in the response durations, and that for these particular schedules, the changes in the response rate were more sensitive than were the changes in response duration.

Response duration is a temporal aspect of behavior and possibly bears some relationship to tempo. There is some evidence that rhythmic patterns and an innate temporal organization of behavior is common to both animals and plants (Brown, 1959). In an intensive study of temporal behavior in human subjects, using 59 different tests, Rimoldi (1951) concluded that "individuals seem to be constant through long periods of time in their tempo characteristics." Rimoldi and Cabanski (1961) have presented some interesting

evidence to indicate that tempo in human subjects has an intra-individual stability that is not unlike that found for response duration in rats. An excellent review of the tempo literature can be found in Cabanski (1961).

CHAPTER III

PROCEDURE AND DESIGN OF EXPERIMENT I

Apparatus

One experimental chamber, having interior dimensions of 12 in. long, 13.5 in. wide, and 7.5 in. high, was used for the entire experiment. The chamber, a bar-pressing apparatus with a lever and dipper at one end of the box, was placed in an insulated cooler chest to eliminate outside lighting and noise disturbances. The dipper was positioned so that it came up at the midpoint of the front panel at floor level and was operated by a motor located within the box and dipper mechanism, wired so that the dipper was only presented in the experimental chamber when the rat pressed the bar with a certain minimum force. The dipper held .12 cc. water, and its complete operation of coming up and returning to the reservoir required 6 sec. (1 sec. coming up; 3 sec. in the chamber; and 2 sec. returning to the reservoir). Therefore, in a 10 minute session a rat could receive no more than 100 reinforcements.

The bar or lever, which was mounted on the front panel, 3 in. to the left of the dipper and 1.5 in. from floor level, consisted of a brass rod with a brass loop, .5 in. in diameter, fused to the end of the rod. The only part of the lever that extended into the experimental chamber was the brass loop. The lever could only be moved in a downward direction (4 mm.)

by Ss, and a 15 gm. downward force on the lever closed a microswitch. The bar was attached to a spring on a set screw which could be tightened or loosened. In this way, the amount of force required to close the micro-switch could be increased or decreased. Since the bar itself weighed only 3 gm., the inertia of the mass of the bar was small enough to be disregarded.

The measure of mean response duration per session (D) was obtained in the following way. The microswitch attached to the bar was in circuit with an electronic pulse former (24 vdc), which was set at a frequency of 10 pulses per second. The coil of a relay (24 vdc) was also in this circuit. Therefore, when the bar was pressed, the relay would close every .10 sec. The normally closed poles of this relay were connected to another circuit between ground (24 vdc) and a stepper switch (Foringer, Model No. 1192). This stepper had 10 positions, each of which was connected to a counter. The closing of the bar microswitch for less than .10 sec. would close the relay once, applying ground to the stepper switch once, which in turn would supply ground from the first position of the stepper switch to the first counter, recording a "0001" in the first counter. (See Figure 1).

In this way a bar press of less than .10 sec. duration was recorded in the first counter; a bar press of between .10 and .20 sec. was recorded in the second counter, etc.; and bar presses over .90 sec. were recorded in the tenth counter. Thus, a frequency distribution of the duration of the bar presses was obtained on the counters during each animal's session in the apparatus.
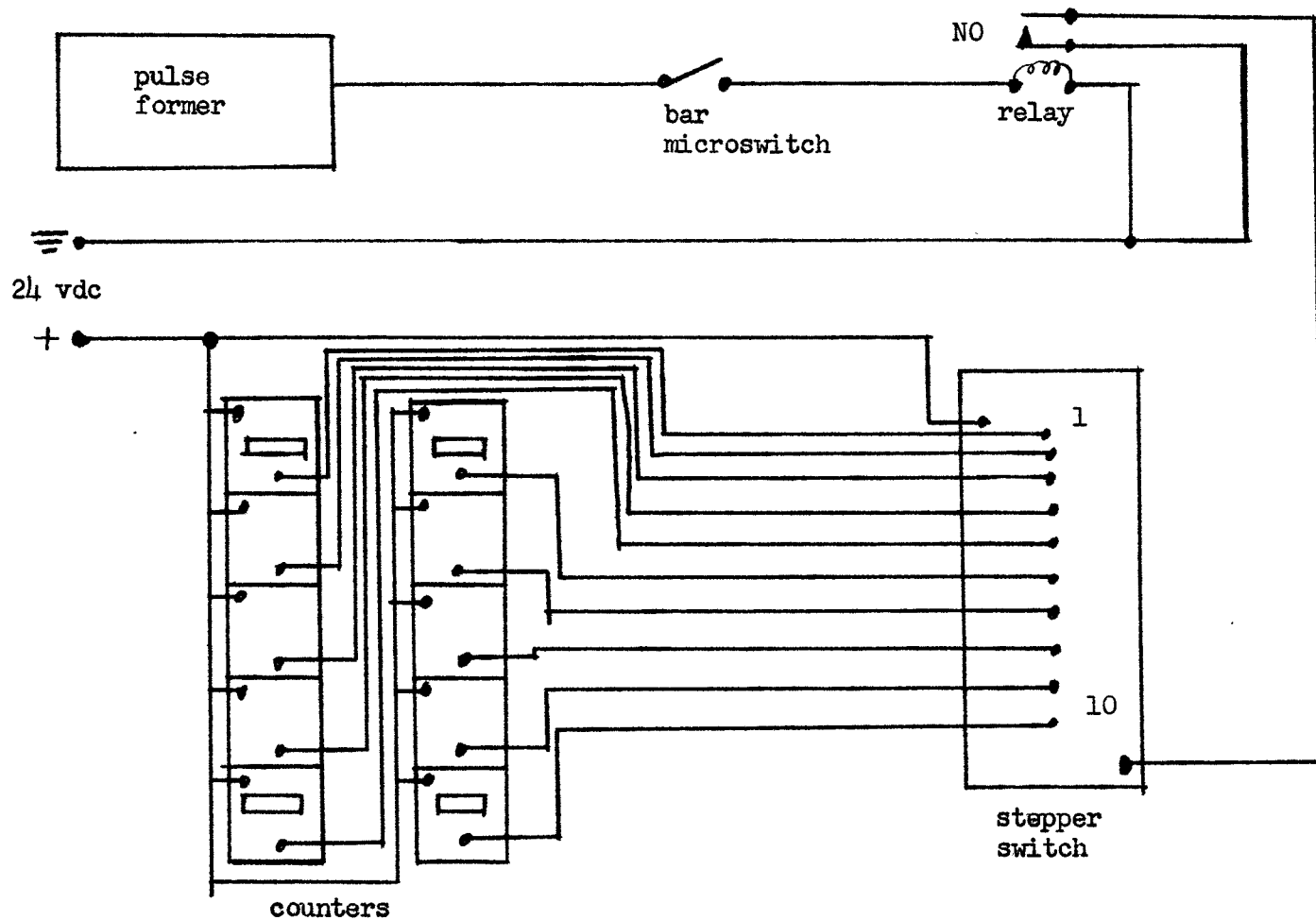
Fig. 1. Simplified Schematic Drawing of Electrical Circuit and Apparatus used in Measuring Response Duration.

Subjects and Procedure

Sixteen male albino rats of the Sprague-Dawley strain were given 44
ten minute sessions (one session a day) in the experimental chamber. Prior
to this they had been given 10 days of training in pressing the bar for water
reinforcement, during which the response rates of the animals stabilized.
The training period was given in the same chamber as the 44 sessions, and
reinforcement was contingent upon a minimum of 15 gm. of force being exerted
on the bar. All Ss were fed on an ad lib schedule of Rockland Rat Diet
pellets and were approximately 150 days old at the beginning of the experi-
ment. In addition to the water received in the experimental chamber, each
rat was given 5 minutes access to water in its home cage after each session.
The hour of testing was approximately the same from day to day (plus or minus
two hours).

The 44 experimental sessions were divided into three sets of trials.
The pre-experimental period consisted of 7 daily sessions in which reinforce-
ment was contingent upon pressing the bar with a minimum force of 15 gm.
Using the data from these sessions, Ss were divided into four matched groups
(4 Ss in each group). The animals were selected so that the mean D of each
group was either .34 or .33 sec. One group (C) was the control and the other
groups (E_1, E_2, and E_3) were experimental.

The experimental period consisted of 25 daily sessions in which the
force contingency schedules varied for the four groups in the following way:
Group C (control) -- reinforcement contingent upon a minimum of 15 gm. of
force exerted on the bar; Group E_1 -- reinforcement contingent upon a mini-
mum of 30 gm. exerted on the bar; Group E_2 -- reinforcement contingent upon

a minimum of 45 gm. exerted upon the bar; and Group E_3 -- reinforcement contingent upon a minimum of 60 gm. of force exerted upon the bar.

The post-experimental period consisted of 12 daily sessions in which reinforcement was contingent upon a minimum of 15 gm. of force exerted on the bar for all animals.

A summary of the experimental procedures in effect for the three sets of sessions is given in Table 1.

TABLE I

FORCE CONTINGENCY SCHEDULES (IN GRAMS) IN EFFECT FOR THREE SETS

OF DAILY SESSIONS FOR MATCHED GROUPS OF ALBINO RATS

Groups	Pre-Experimental (7 sessions)	Experimental (25 sessions)	Post-Experimental (12 sessions)
C	15 gm.	15 gm.	15 gm.
E_1	15 gm.	30 gm.	15 gm.
E_2	15 gm.	45 gm.	15 gm.
E_3	15 gm.	60 gm.	15 gm.

CHAPTER IV

RESULTS OF EXPERIMENT I

The results of this study are summarized in Table 2, which shows the changes in mean Ds and mean response outputs for the four groups of rats during the three sets of trials.

TABLE 2

MEAN AND SD OF RESPONSE OUTPUT AND DURATION (SEC.) OF FOUR GROUPS OF RATS
UNDER VARYING FORCE CONTINGENCY SCHEDULES

| Groups | Pre-Experimental | | | | Experimental | | | | Post-Experimental | | | |
| | Resp. | | D | | Resp. | | D | | Resp. | | D | |
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
C	139	23.95	.34	.08	113	30.06	.35	.10	102	15.83	.31	.10
E_1	131	29.09	.33	.10	98	23.41	.24	.06	97	23.41	.29	.10
E_2	144	46.40	.34	.08	84	20.02	.20	.04	94	16.93	.32	.11
E_3	109	26.69	.33	.10	85	28.61	.19	.03	90	13.47	.43	.11

Two analyses of variance were performed to test the significance of the differences in D (McNemar, 1955). An analysis of the mean Ds for the experimental sessions is given in Table #3. This analysis indicates that there

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were significant decreases in D as a result of increases in the force contingency schedules.

TABLE 3

ANALYSIS OF VARIANCE OF MEAN Ds FOR EXPERIMENTAL SESSIONS

Source	df	SS	Variance	F	P
Between	3	.06	.0202	6.81	< .01
Within	12	.04	.0030		

In Table 4 an analysis of the mean Ds of the experimental and post-experimental sessions is given. The interaction between the groups and the two sessions shows that the size of the increase in D, occurring as a result of decreases in the force contingency schedule, is a function of the level of D prior to the decrease in the force contingency schedule.

Figures 2, 3, 4, and 5 indicate how the mean Ds and mean response outputs varied in the four groups of rats, day by day, during the 44 sessions of the experiment. The most obvious points of interest in these figures are the transition points between changes in force contingency schedules. Group C, which was under a 15 gram schedule for all three sets of trials, shows no sizable increase or decrease in the mean D at the first transition point (between the pre-experimental and experimental sessions) or the second transition point (between the experimental and post-experimental sessions). Group E_1, however, when changed from a 15 gm. to a 30 gm. schedule, showed a

decrease of .08 sec.; when changed back to a 15 gm. force contingency schedule showed an increase of .15 sec. When Group E_2 was changed to a 45 gm. schedule, the D decreased .19 sec., and increased .36 sec. when put back on the 15 gm. schedule. Group E_3, in its transitions from the 15 gm. schedule to 60 gm. and back to 15 gm., decreased .12 sec. and increased .45 sec., respectively.

TABLE 4

ANALYSIS OF VARIANCE BETWEEN EXPERIMENTAL AND POST-EXPERIMENTAL
SESSIONS AND FOUR GROUPS OF RATS

Source	df	SS	Variance	F	P
Rows[*]	12	.1026	.0086	----	----
Blocks[**]	3	.0263	.0088	4.29	< .05
Columns[***]	1	.0750	.0750	36.73	< .001
B $\times$ C	3	.0808	.0269	13.19	< .001
Remainder	12	.0245	.0020	----	----

[*]Individual rats   [**]Four groups of rats
[***]Experimental and post-experimental sessions

Considering the mean Ds of the groups for each block of trials (see Figs. 6-9), the stability of the control group's D is again noted. The experimental groups, however, show a progressively sharper decrease in D with a greater force required to obtain reinforcement. Similarily, when the experimental groups were changed back to the 15 gm. schedule, the greater the change in the schedule, the greater was the increase in D.
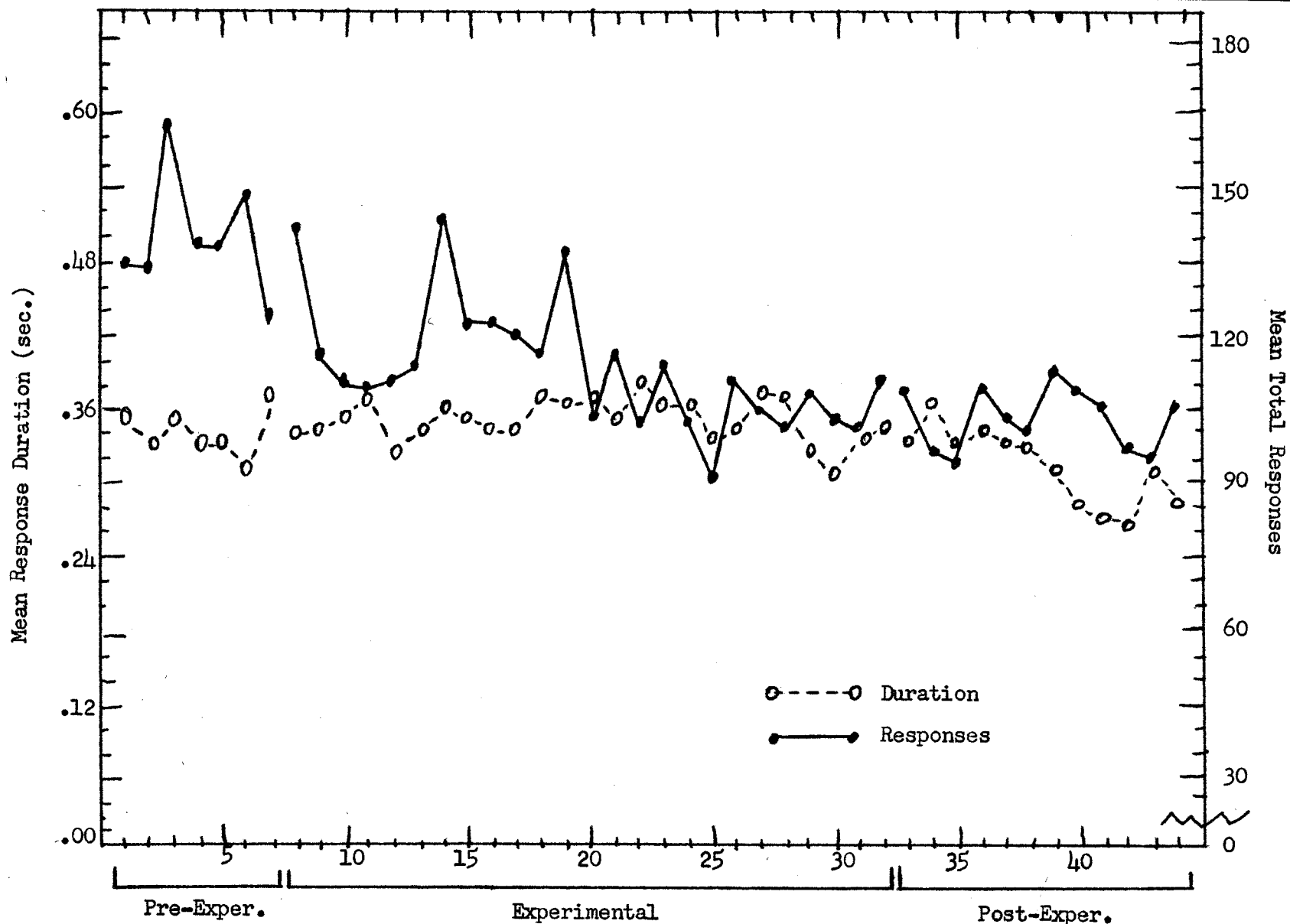
Fig. 2. Mean Total Responses and Mean Response Durations of Group C for 44 Daily 10 Minute Sessions under Three Force Contingency Schedules (15gm. - 15gm. - 15gm.).

Fig. 3. Mean Total Responses and Mean Response Durations of Group E₁ for 44 Daily 10 Minute Sessions under Three Force Contingency Schedules (15gm. - 30gm. - 15gm.).

Fig. 4. Mean Total Responses and Mean Response Durations of Group E_2 for 44 Daily 10 Minute Sessions under Three Force Contingency Schedules (15gm. - 45gm. - 15gm.).
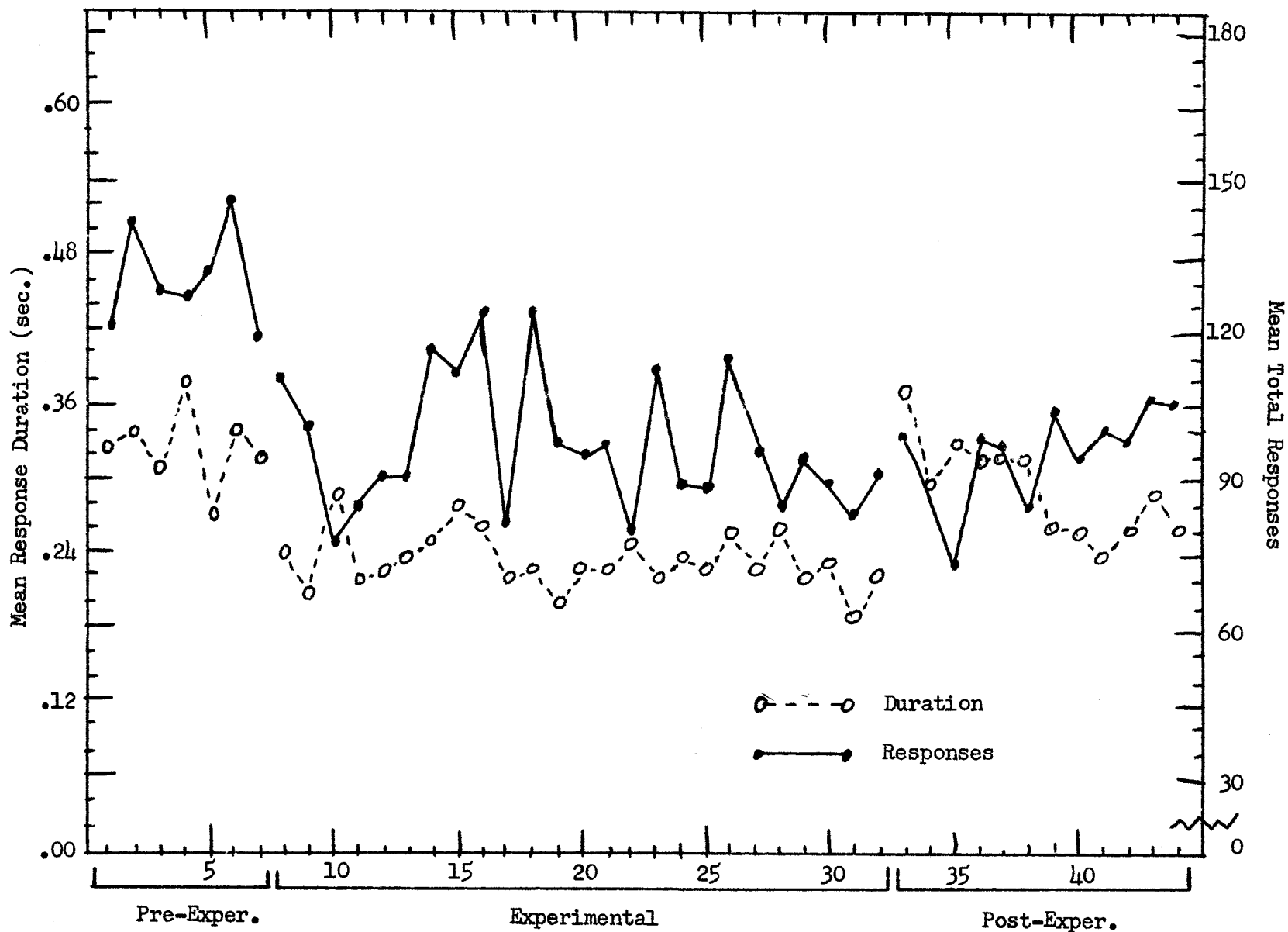
Fig. 5. Mean Total Responses and Mean Response Durations of Group E$_3$ for 44 Daily 10 Minute Sessions under Three Force Contingency Schedules (15gm. - 60gm. - 15gm.).
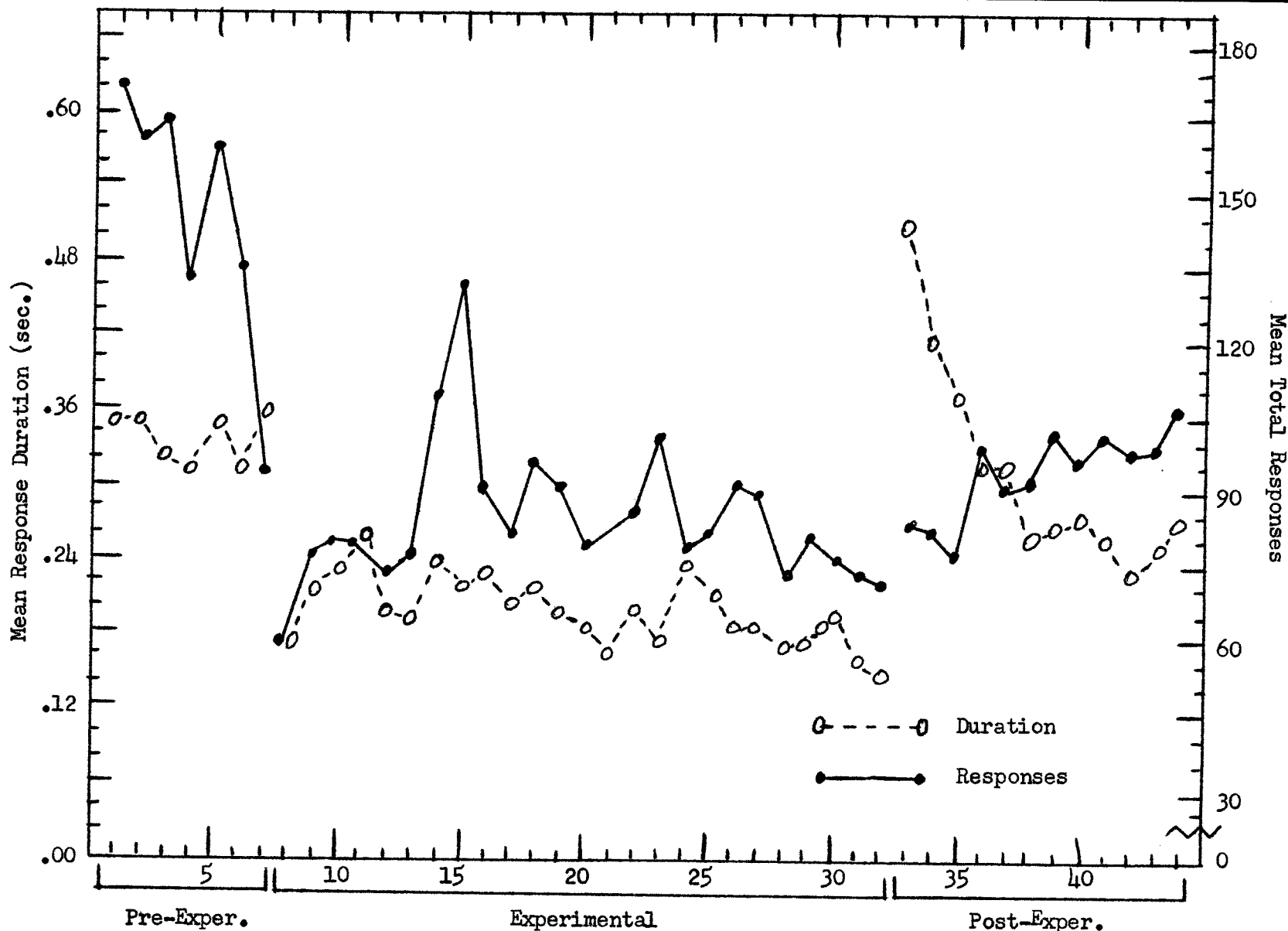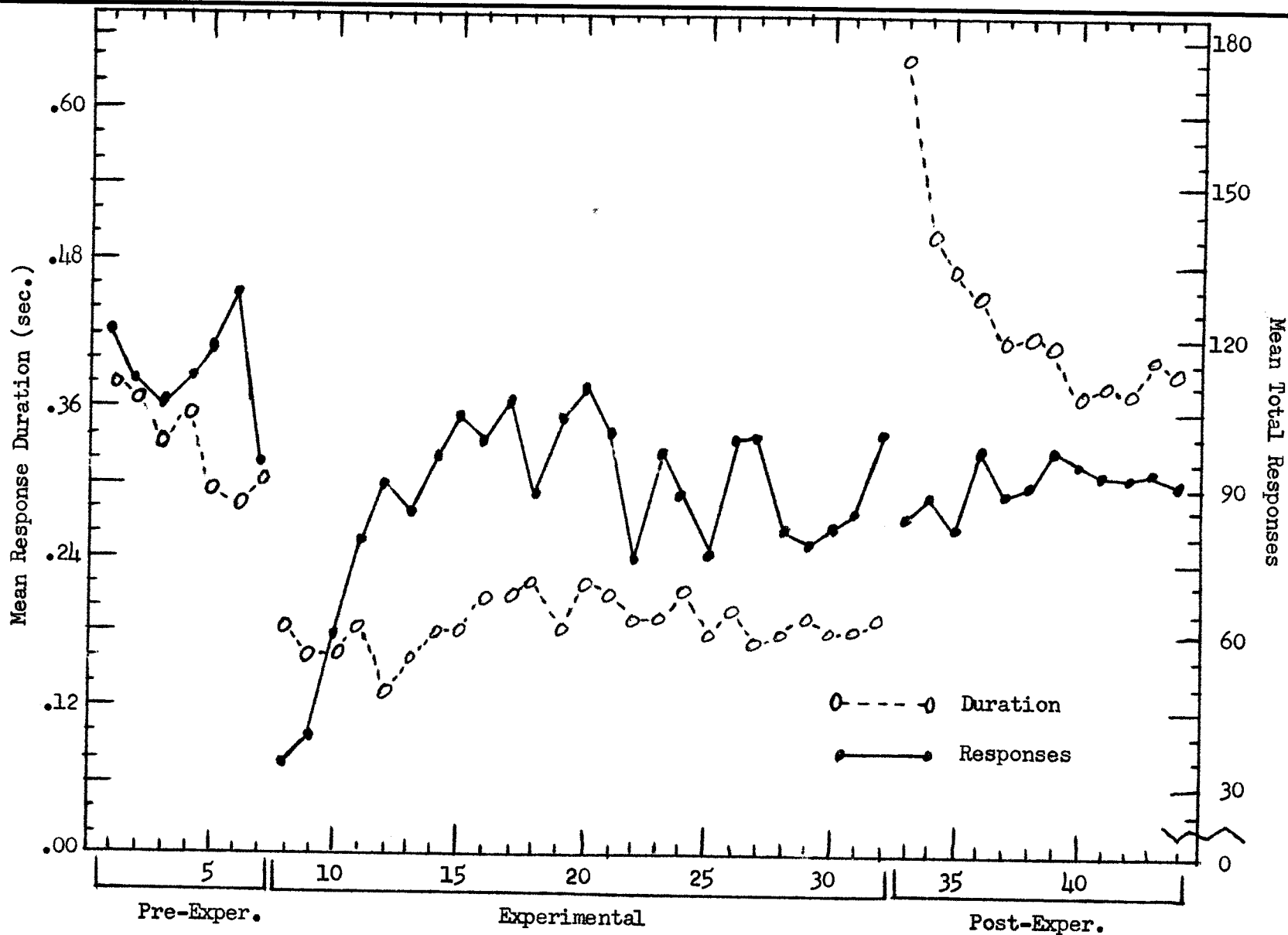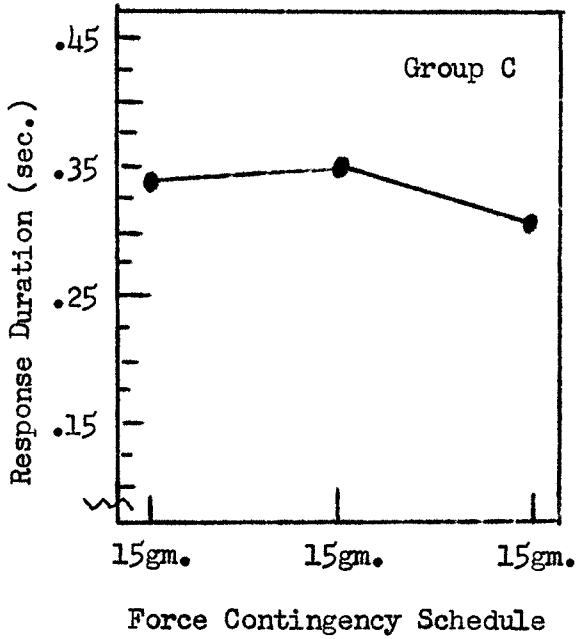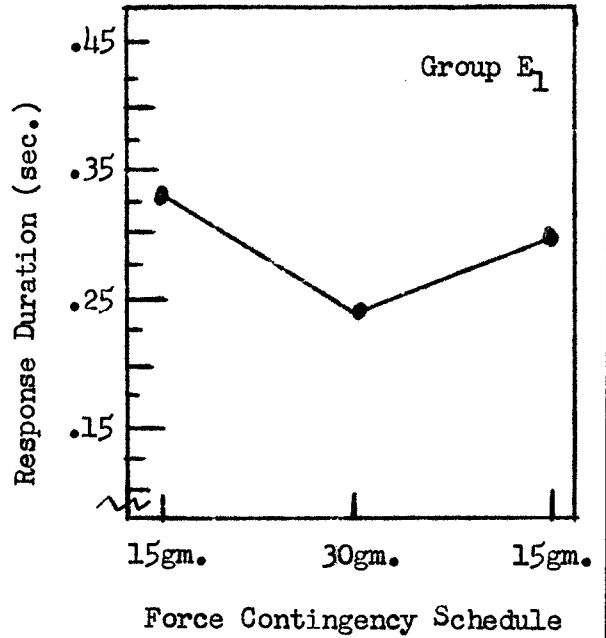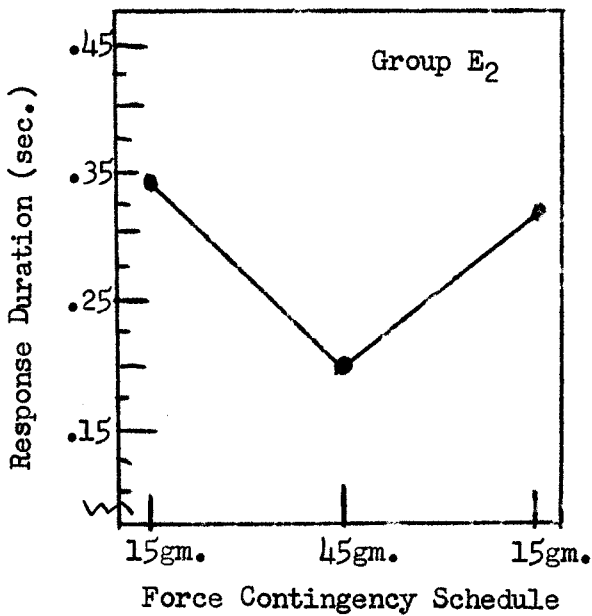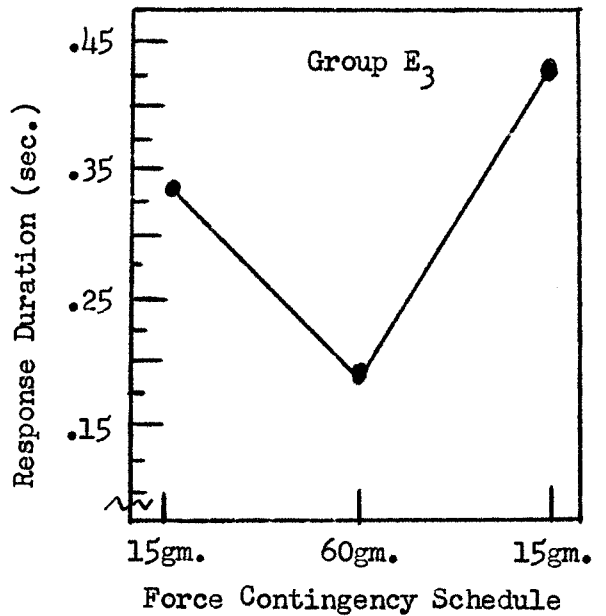
Figs. 6-9. Mean Response Durations of Four Groups of Albino Rats under Three Force Contingency Schedules.
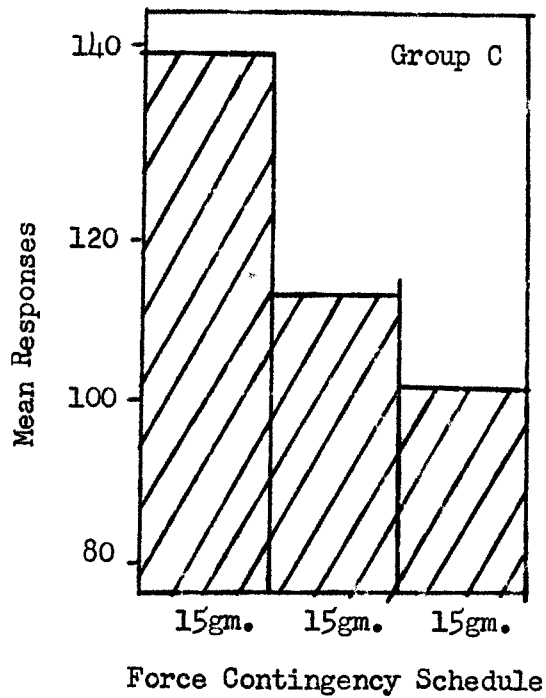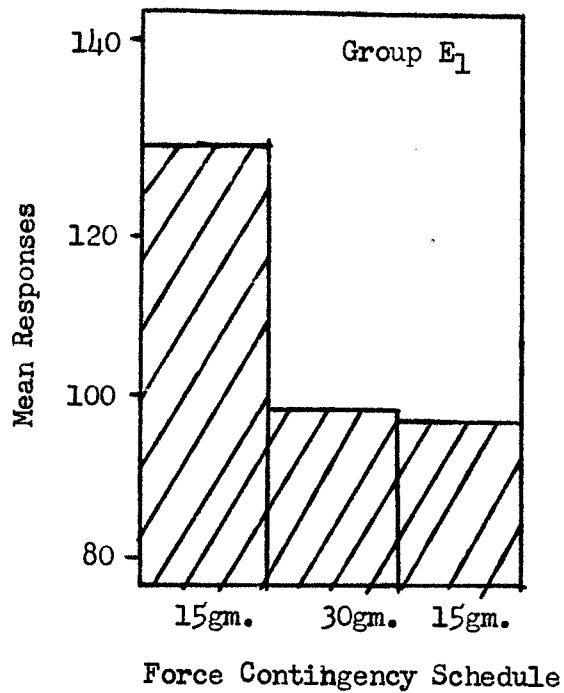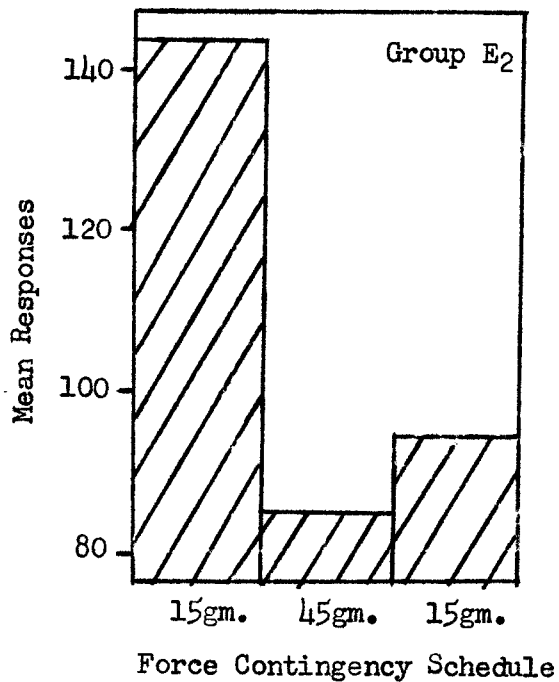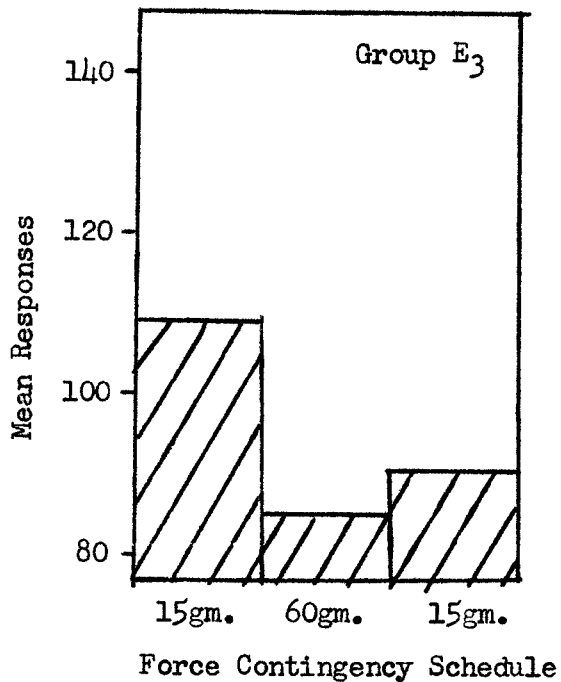
Figs. 10-13. Mean Responses of Four Groups of Albino Rats under Three Force Contingency Schedules.

In Figures 10-13, the mean total responses given during the three sets of trials are presented. The control group shows a decrease from 139 to 113 to 102, over the three sets of trials. Group E_1 had a mean response output of 131 for the pre-experimental sessions, and 98 and 97 for the experimental and post-experimental sessions. Both Groups E_2 and E_3 showed similar response trends over the three sets of trials. Group E_2 gave 144, 84, and 94 responses, respectively, for the pre-experimental, experimental, and post-experimental sessions, whereas, Group E_3 gave mean response outputs of 109, 85, and 90.

Figure 14 represents the mean Ds for the experimental sessions of the four groups of rats plotted as a function of the force contingency schedules.
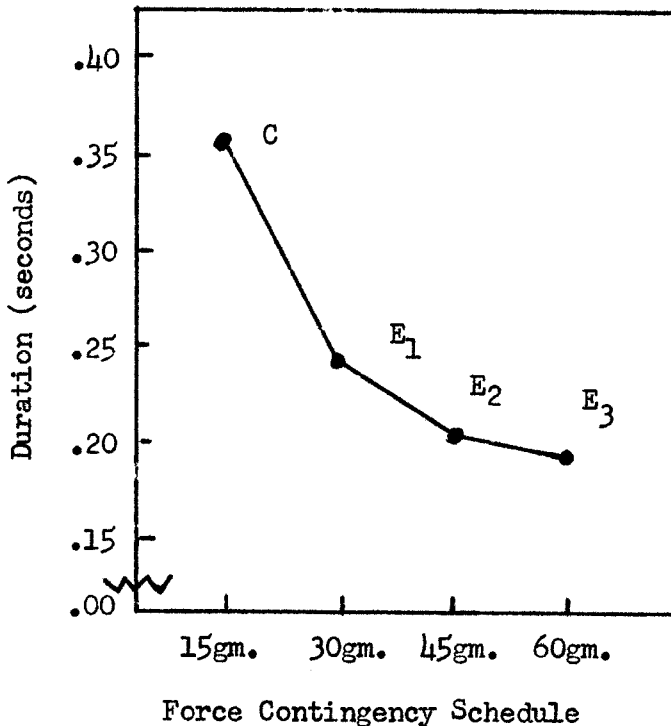
Fig. 14. Mean D of Four Groups of Rats under Four Force Contingency Schedules.

CHAPTER V

DISCUSSION OF EXPERIMENT I

It is clear from the results of this experiment that changes in force contingency schedules have marked effects on the duration of response. The Ds of the control group, which received no change in schedule, did not significantly change during the three sets of trials. The experimental groups, however, showed significant differences in their Ds after the changes in force contingency schedules.

There is an apparent inverse relationship between D and changes in force contingency schedules (see Fig. 14), since an increase in the force schedule is followed by a decrease in D. That this is not a linear function may be due to the rat approaching the lower limit of its D; i.e., it is not physically able to press the bar for a shorter period. It is doubtful the limitations could be in the apparatus, because it was found that presses as short as .05 sec. were sufficient to be recorded and to trigger reinforcement. In changing from a high force contingency schedule to a low force schedule, there is also an inverse relationship: the greater the decrease in the force schedule, the greater the increase in D.

The effect of changing force contingency schedules upon D was not temporary, for there was no indication throughout the 25 sessions of the experimental trials that the Ds would ever return to their normal level, as long

as the animals remained on the high force schedules. Once the 15 gm. schedule was reinstated, however, the Ds no longer remained decreased. Apparently, increases in force contingency schedules have a different effect on D than do changes in reinforcement schedules of the crf (continuous reinforcement) and FR (fixed ratio) types. Schaefer and Steinhorst (1959) found that changes in schedules of this latter type produced only temporary increases in D under the new schedule, with D returning to its normal level after five days. The present experiment, on the other hand, has indicated that increases in force contingency schedules have permanent decreasing effects on the D during the entire period the animal is on the new force schedule.

However, decreases in force contingency schedules and changes from crf to FR schedules appear to have similar effects on D, for in both there is an initial increase in D. The difference is that a change from crf to FR increases D, which eventually returns to the D obtained under crf; whereas, the results of decreasing force contingency schedules, for example, from 45 gm. to 15 gm., will be a temporary large increase in D with a gradual return to the D of the 15 gm. schedule, not of the 45 gm. schedule (see Fig. 4). The relation of this initial overcompensation in D to compensatory rates of bar pressing (Ferster and Skinner, 1957) would be interesting to investigate.

The control group's data support the findings of Schaefer and Steinhorst (1959) that D is a stable measure of behavior, provided that the force contingency schedule is held constant. D, therefore, should not be considered as an absolute value, but should always be regarded in terms of D related to a particular force contingency schedule. A D obtained from a rat in an

apparatus that requires the exertion of 15 gm. of force on the bar to trigger reinforcement will be longer than the D obtained for the same rat on a 30 gm. bar.

In addition to decreasing the D, an increase in the force contingency schedule also reduced the standard deviations of the durations (see Table 2). If D is to be used as an experimental measure of behavior, in drug studies, for example, a large range of variation in D may be needed, which would require the use of a low force contingency schedule. Studies on timing behavior, therefore, should not overlook the force required to perform the response, since the standard deviation of the durations is reduced under higher force contingency schedules.

The construction of the apparatus used in this study allowed measuring D for a bar press sufficiently strong to overcome the combined resistance of a spring and the microswitch which served to trigger the reinforcement. Although other designs are possible, the present apparatus conforms to lever arrangements that are conventionally used. The topography of the response begins to change quite drastically when devices are used which differ from that described.. The response utilized in this study was an unmistakable bar press, not a jiggle of the bar, not a biting of the bar, etc.

It is true that the definition of D as used in this study may not be the one in which another investigator may be interested. It could be said that the operations performed do not measure the "true" D. Should the "true" D be measured from the exertion of the tiniest, infinitesimal force on the bar? Going back even further, the D might be considered as the beginning of the excitation of muscle tissue. These are only two alternate definitions of D.

In view of these other possible definitions of D or duration of response, the conclusions made from this study must be regarded in terms of D defined as the amount of time the microswitch was closed for each response.

In a previous study (Schaefer, 1960), it was found that rats, run for at least 12 daily periods in a bar pressing apparatus, can learn the systems limitations of that apparatus. An inspection of the mean response outputs (see Figs. 10-13) for the four groups of rats used in the present study tends to support this conclusion. Since the dipper motor could deliver no more than 100 reinforcements per 10 minute session, total response outputs of over 100 per session involved wasted effort. Groups C and E_1 progressively reduced their responses until during the post-experimental period they approached 100. The response outputs of E_2 and E_3 may have been influenced by the change to higher force contingency schedules, for their responses were reduced to levels below 100. However, when put back on the 15 gm. schedule in the post-experimental period, their mean response outputs also approached 100. It seems that the animals were able to learn the limitations of the apparatus, and adjust their behavior to operate at a more efficient level.

CHAPTER VI

PROCEDURE AND DESIGN OF EXPERIMENT II

Apparatus

A semi-soundproof testing booth in the Loyola perception laboratory (Lake Shore Campus) was used for all experimental sessions. The dimensions of the room were 7 feet wide, 11 feet long, and 7.5 feet high. An exhaust fan, operating continuously to provide for ventilation, also served to mask any distracting auditory stimuli. The room was illuminated by fluorescent lighting.

A large table (3 feet by 6 feet) was centered in the room with an opaque screen placed on the table so as to divide it into two 3-foot square sections. At one end of the table, near the door of the booth, was placed a chair for S. A chair for E was located at the opposite end. The screen concealed E and the recording apparatus from S's view (see Fig. 15).

The apparatus located at the S end of the table consisted of two rectangular boxes, one placed on top of the other. The lower box, covered entirely by black cardboard, had a response lever projecting from the front side. The upper box, constructed of black galvanized metal, had a reaction time key in the upper right hand corner of the front side, and a circular opening to the left-center of the key. Just below this opening was a metal cup. Placed on the table, to the left of the boxes, was a 60 watt light bulb,

mounted in a socket on a board, with wires going to the rear of the lower box. In front of the bulb was placed a stack of bingo cards. To the right side of the boxes was a large metal cup and a supply of bingo markers (see Fig. 16).

Enclosed in the upper box was a marble supply and motor, which, when operated, delivered marbles down a tube to the opening on the front surface of the box. The response lever (lower box) was connected to a microswitch, so that when the lever was pressed with a force of at least 63 gm., an electrical circuit was closed, starting a response duration clock. When the lever was released the circuit opened again, stopping the clock. Simultaneously, upon the release of the lever, another circuit was closed, operating a motor which delivered one marble down the tube and into the metal cup (see Fig. 17).

A black bingo number was painted on each of the 75 multi-colored glass marbles used in the apparatus. Standard bingo cards and wooden markers were also used.

The reaction time key (upper box) was connected in a series circuit with the stimulus key and the reaction time clock. A press of the stimulus key by E had the simultaneous effect of lighting the 60 watt bulb and starting the reaction time clock. This clock continued running until the reaction time key was released by S.

The recording apparatus, consisting of the response duration clock and the reaction time clock (both calibrated in 100s of a second), was placed at the E end of the table. The reaction time stimulus key was located midway between the two clocks.

Subjects and Procedure

All 21 subjects were male students (17 to 19 years old) of Loyola

University and were enrolled in freshman general psychology courses. The

Ss volunteered for the experiment by writing their names on a sign-up sheet,

which was circulated in the psychology classes on the Lake Shore Campus. In

addition to briefly describing the experiment as a study of luck in playing

bingo, the sheet explained that three cash prizes ($15, $10, and $5) would

be given to the winners of the greatest number of games. The students were

also told that this experiment would complete their obligation of serving

as subjects in experiments, a requirement for freshman psychology students.

Each S came in for an individual 15 minute session for 21 consecutive

school days (i.e., not including Saturdays, Sundays, or holidays). The first

two sessions consisted of an orientation in which each S was given more

details about the procedure, and the testing time for each day was arranged.

The Ss were told the experiment was a study of the day to day changes

in luck while playing a game of chance over a period of days. They would

receive 50 bingo numbers each day and their daily score would be determined

by the number of games won and the actual numbers they received. They were

led to believe that these scores were to be determined by a complex scoring

method so that they would never know how well they were doing, nor could

they compare their achievement with any other subject.

Following the two orientation sessions were 18 sessions in which the Ss

played bingo. These sessions were divided into three groups: 9 pre-experi-

mental, 5 experimental, and 4 post-experimental sessions.

During the 9 pre-experimental sessions, all 21 subjects were tested

under the following procedure: S came into the testing booth at the pre-
scribed time and sat in the chair placed directly in front of the response
and marble apparatus. S then selected one bingo card from the pile of cards
found at the left of the apparatus and placed it on the table directly in
front of the response lever. From a container of wooden markers S took one
marker and placed it in the free spot on the bingo card.

E, first recording the subject's name and date on the data sheet, then
took his chair on the other side of the screen and asked S to begin whenever
he was ready. (S was given the option of using either the right or left hand,
but the same hand was to be used to depress the lever for all sessions.) S
then proceeded to press the response lever. After S released the lever, a
marble was ejected into the marble cup. S then read out loud the number on
the marble, and if that number was found on the bingo card S marked it with
a wooden marker. (S was led to believe that E was recording the actual bingo
number received as called out by the subject, and that the cards would be
checked after each game. E was actually recording the duration of each lever
depression as it was made.) The marble was then placed in a cup to the right
of the bingo card. S then proceeded to press the lever until a game of bingo
was won (i.e., five consecutive markers, horizontally, vertically, or
diagonally). When S won a game he said "bingo" and E took his card and
placed it behind the screen. The marbles already received were then replaced
in the marble apparatus and the subject was allowed to select another card.
The session was concluded when S had received a total of 50 bingo numbers.
Each daily session followed the same method, with E reminding S which hand
he had used the day before.

For the next 5 sessions (experimental) the subjects were divided into two groups: 11 control subjects (group C) and 10 experimental (group E). These groups were determined by selecting subjects so that the mean response duration of each group for the first 9 sessions was approximately the same. During the experimental sessions the procedure for group C remained the same, but the procedure for group E was varied in the following way. Having been told that the relationship between luck and reaction time was now going to be studied, S was instructed to press the reaction time key, and to hold it down until he saw the 60 watt bulb illuminated. Then he was to release the key as quickly as possible. Following each reaction time response, S was to press the response lever as usual to obtain marbles.

E followed the usual procedure in reaction time testing by giving a ready signal (the word "ready"), which preceeded the light stimulus by various times between 0 and 3 seconds. In addition to recording response duration, E also recorded the reaction time after each of the 50 stimulus presentations.

The procedure for the final 4 sessions (post-experimental) was the same as that of the pre-experimental sessions for both groups.

On the 21st session, no bingo games were played. The subjects were asked three questions by the experimenter. (1) To the best of your knowledge, were you suffering from any illness, drug effects, or hangover while playing bingo during any of the sessions? (2) Did anyone tell you this experiment was designed to study something other than what we told you? (3) What are your general impressions about the experiment?

After E recorded the answers to these questions, the subjects were thanked for their cooperation, the prize winners were announced and given their money.
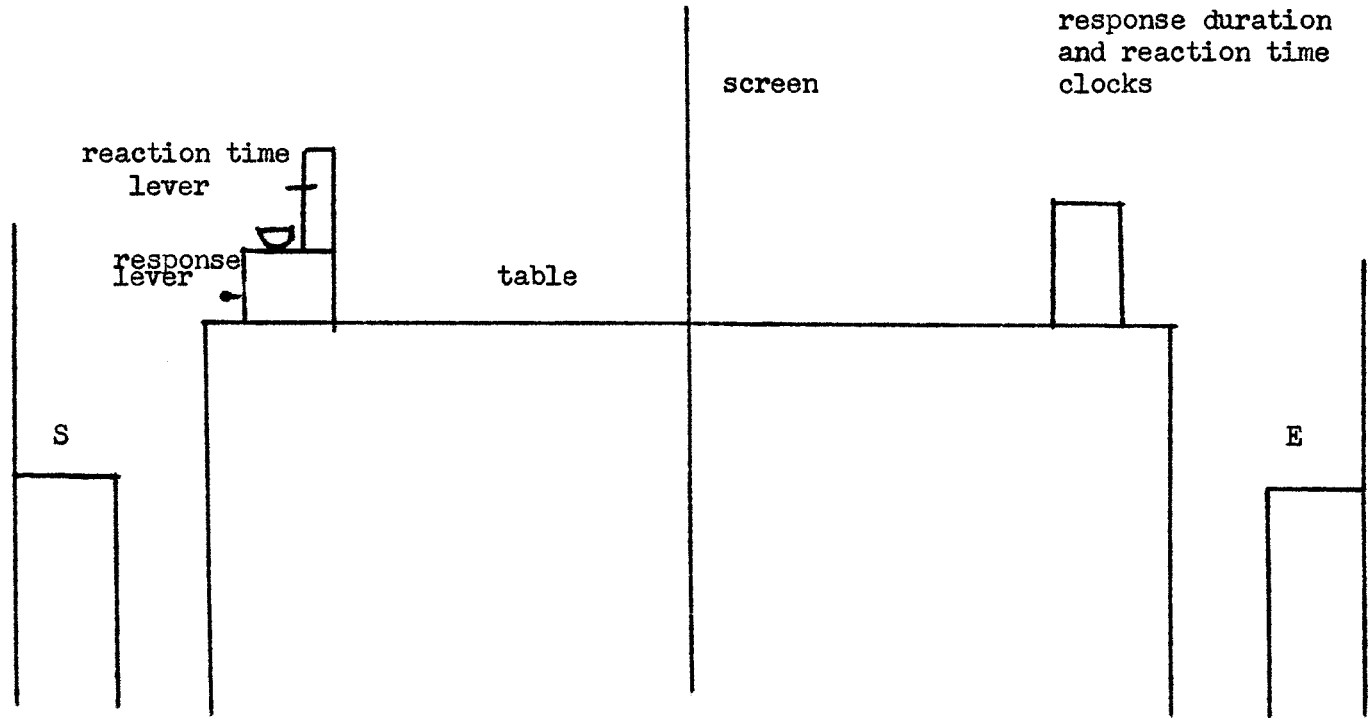
Fig. 15. Sketch of Side View of Apparatus Arrangement used in Measuring Human Response Duration.
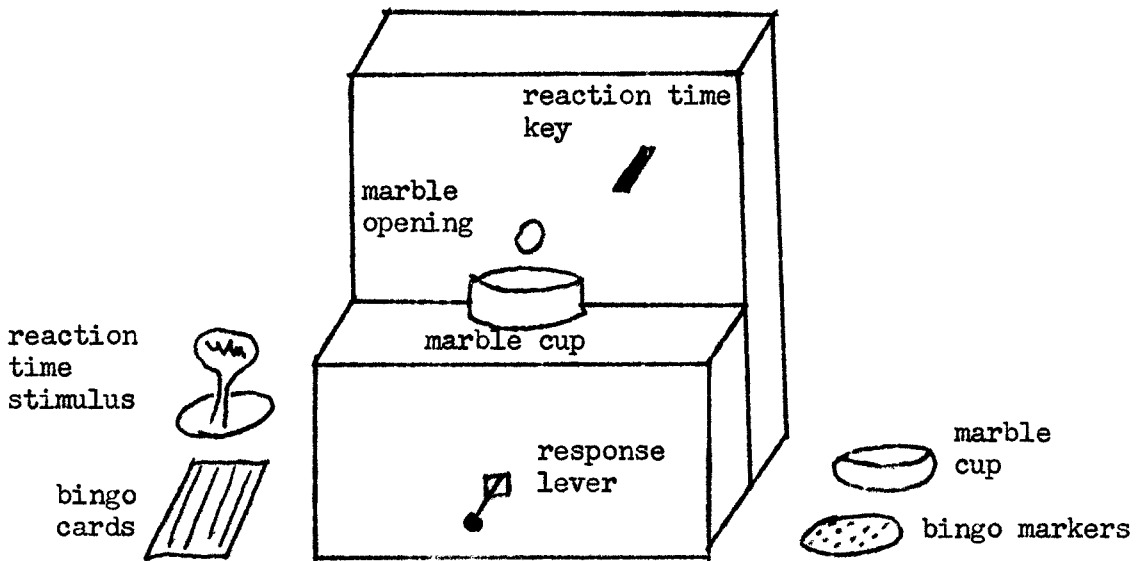
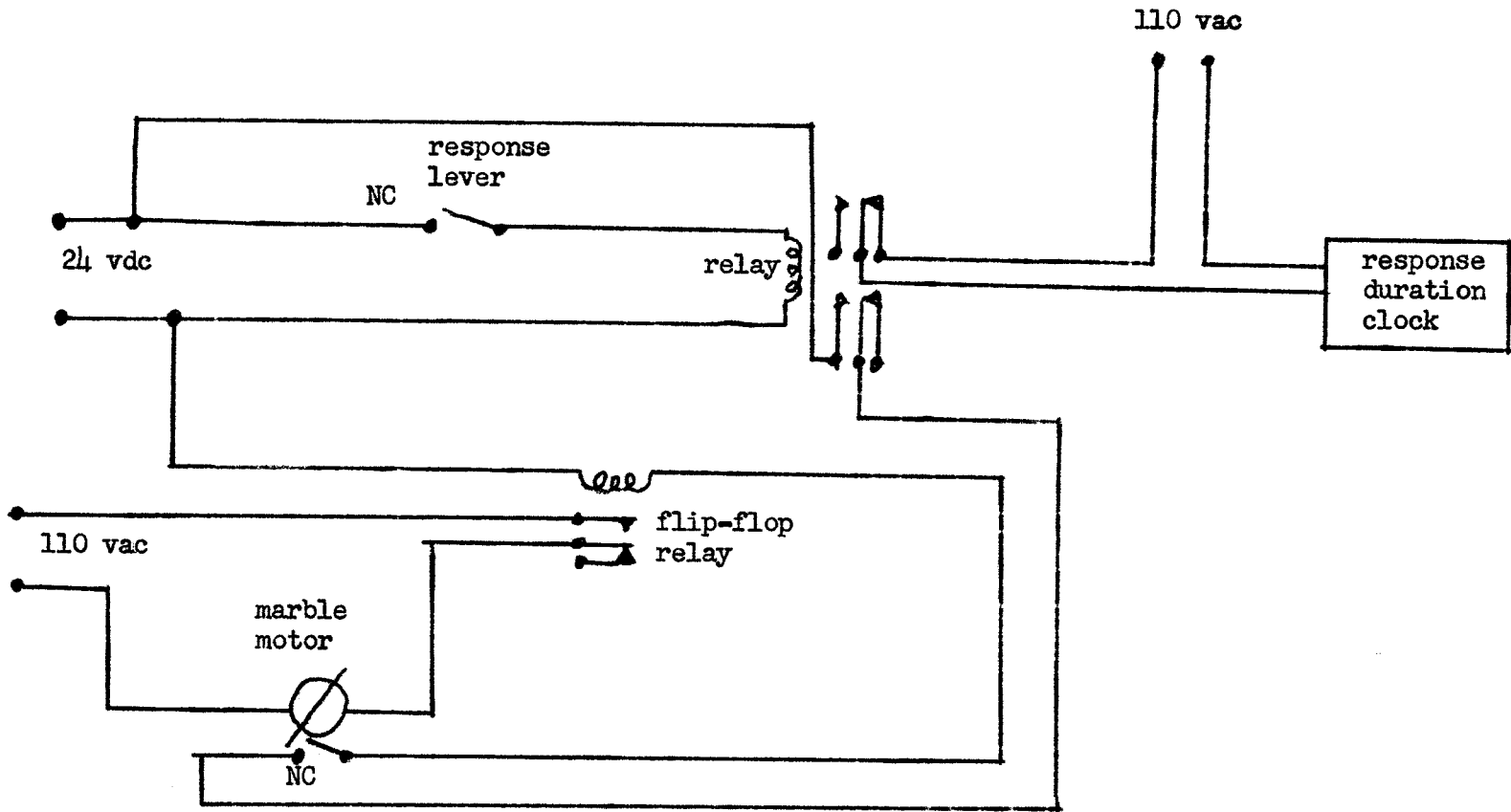Fig. 16. Sketch of Response Duration and Marble Apparatus used in Measuring Human Response Duration.

Fig. 17. Simplified Schematic Drawing of Electrical Circuit used in
Measuring Response Duration.

CHAPTER VII

RESULTS OF EXPERIMENT II

Mean response durations were obtained for each subject after each daily session. These were then used to calculate the group means for each day.

Figure 18 gives the mean response durations of group C and group E for the 18 testing sessions. The first gap in the plotted data represents the end of the pre-experimental sessions and the beginning of the experimental sessions. During the experimental sessions, group E was required to perform the additional reaction time task, whereas the task of group C remained the same. The second gap in the plot represents the end of the experimental sessions and the beginning of the 4 post-experimental sessions.

In Figure 19 the standard deviations of the group mean response durations are given. The gaps represent the same changes as in Figure 18.

The mean response durations for the two groups are given in Figure 20 for the three sets of sessions. Similarily, the standard deviations for the group response durations are given for the pre-experimental, experimental, and post-experimental sessions in Figure 21.

Using a Mann-Whitney U test, the difference in mean response duration for group C and group E, during the experimental sessions, is significant. The U was found to be 86, and using the correction for ties a z of 2.4 was obtained, which represented a p of .0082. The Mann-Whitney test was used because the variances of the group mean response durations were non-homo-

Fig. 18.   Mean Response Durations of Group C and Group E during 18 Daily
Bingo Sessions.

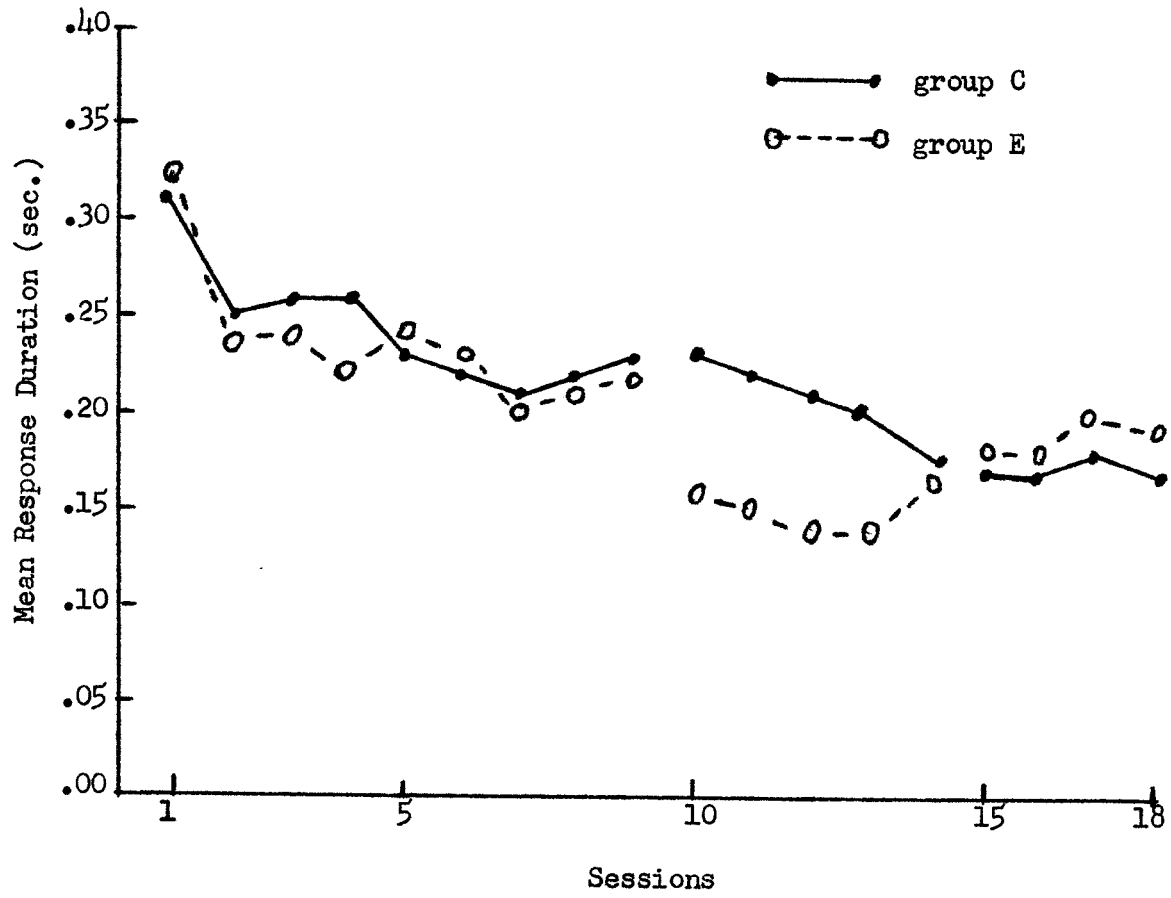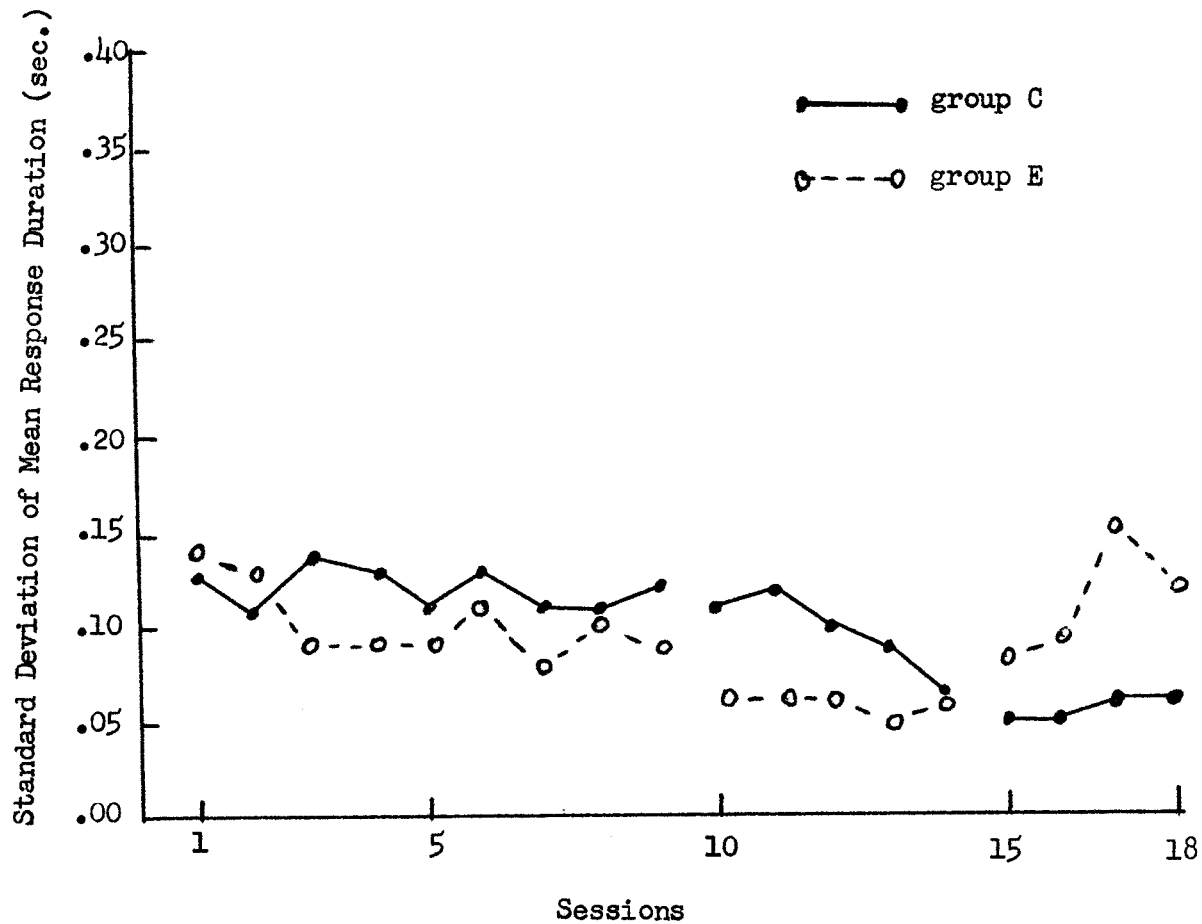Fig. 19. Standard Deviations for Mean Response Durations of Group C and Group E during 18 Daily Bingo Sessions.
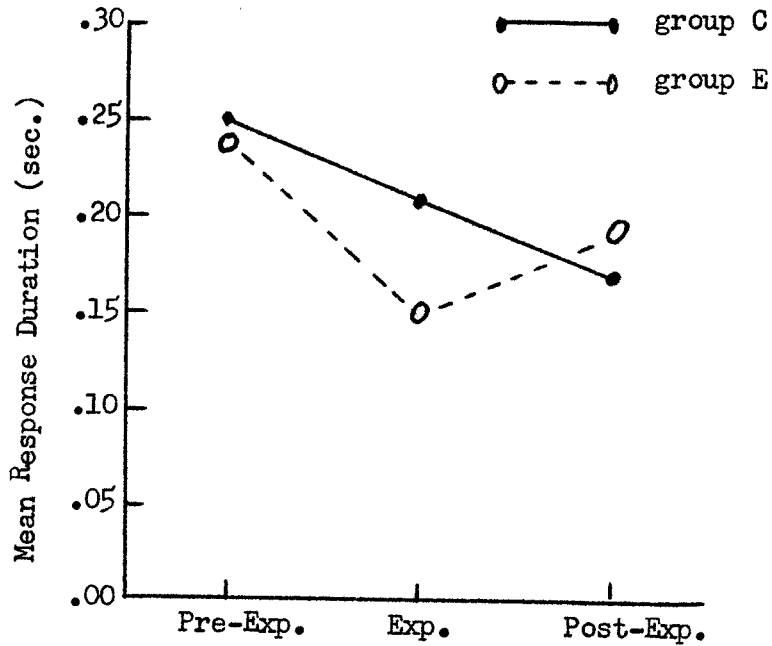
Fig. 20. Mean Response Durations for Group C and Group E during the Pre-experimental, Experimental, and Post-experimental Sessions
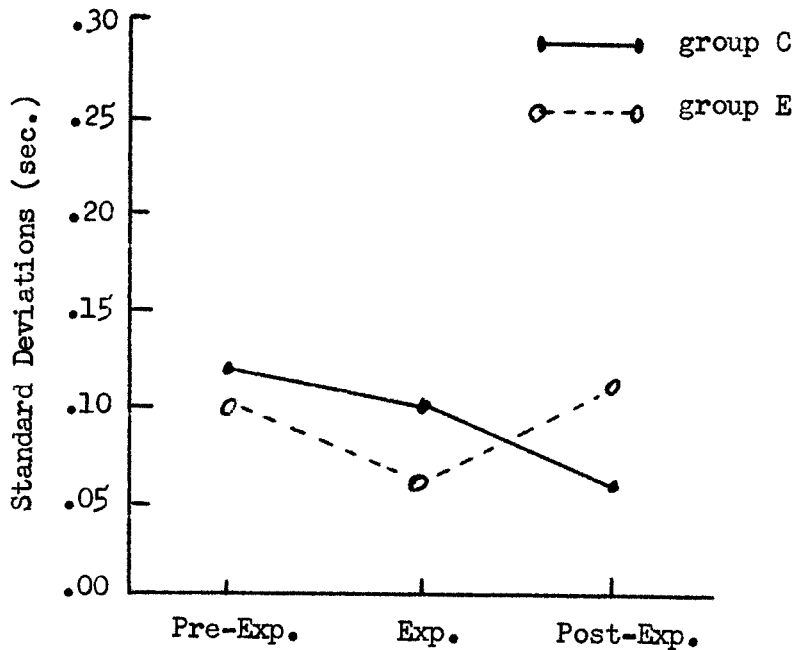
Fig. 21. Standard Deviations of Mean Response Durations for Group C and Group E during the Pre-experimental, Experimental, and Post-experimental Sessions.

genous (Siegel, 1956).

No attempt was made to analyze the reaction times obtained from the experimental subjects (group E), because the range of reaction times for all subjects and all days was extremely small. The lowest RT was .15 sec. and the highest was .21 sec.

To the first two questions asked of the subjects at the end of the experiment all the answers were "no". The answers to the third question indicated that all subjects were very interested in the experiment, especially because of the cash prizes. About one-third of the subjects suspected that the experimenter was not telling them the real purpose of the study, but no subject reported that he had guessed what measurements were being recorded, other than reaction times and bingo numbers.

CHAPTER VIII

DISCUSSION OF EXPERIMENT II

An inspection of the data presented in Figures 18 and 20 gives a clear picture of the gradual decrease in response duration for group C over the 18 sessions. Although the decrease after the first session is the largest, a steady trend is apparent until finally the response duration reaches a low of .17 sec. on the last session. Margulies (1961) also has noted that duration declines during regular reinforcement with rats as subjects. It is of course rather obvious that even a simple task, such as pressing a lever, can undergo some adaptation, and eventually be executed in a more efficient manner.

The dispersions of the response durations of group C (see Figures 19 and 21) also seem to follow a decreasing trend. This same effect was found by Millenson and Hurwitz (1961) and is related to the decrease in duration, since an increase in efficiency is more than likely to show up in both lowered time and lowered variance.

The important point to note about the decreases, in terms of finding sensitive measures of behavior, is that after the first two sessions, there are very gradual decreases. Therefore, any change in duration that is larger than .04 sec. will be easily seen.

This is exactly what is found when the data of group E is inspected.

During the pre-experimental sessions the durations of group E follow very closely those of group C. However, once the reaction time task is introduced to group E, there is a dramatic decrease of .06 sec. in their response durations. The duration was significantly altered from that of the control group. When the reaction time task was no longer given during the post-experimental sessions, the duration increased again to a point near its previous level.

There are many possible explanations for the decreasing effect of the reaction time task on response duration (set, muscle tension, stress, etc.), but to determine these was not the purpose of the study. It was simply guessed that a response to a reaction time situation might alter duration. That was the sole reason for picking this particular task. The fact that response duration could be altered at all is more important in terms of this study than why it was altered.

It should be noted that in group C response duration never reached a clear lower limit. This was probably due to the relatively small number of sessions in which the subjects were tested. By extending the 18 sessions to 30 or more, it is likely that the response duration would finally stabilize. Since this study cannot show stable durations, however, it cannot be concluded that human response durations are as stable as those found in other organisms.

On the other hand, since human response durations were found to follow gradual and consistent decreasing trends, and since it was also found that the durations can be altered, it can be concluded that human response durations may be as sensitive as those found in other organisms.

CHAPTER IX

GENERAL DISCUSSION

The two studies given above were presented as independent experiments. No attempt was made to compare response duration in rats and humans. To say that a human pressing a lever for cash prizes is performing a comparable task to a rat pressing a bar for water is, putting it mildly, going beyond the data. The whole point of these studies was to furnish additional evidence that response duration is a reliable and sensitive measure of behavior, one that should be utilized in forming new schedules of reinforcement. Since pharmacologists and neurochemists use operant conditioning techniques with both rats and humans, it was decided to study response duration in both.

The data presented in Figures 3-5 clearly indicate that D is often more sensitive and reliable than response rate. The response rate (actually response output is plotted, but since the sessions were all the same length, the rates are directly related to output) has many fluctuations, whereas the D remains stable until the schedule is changed. Then D shows drastic effects, while the response rate continues to fluctuate. There is no difficulty picking out the changes in schedules using D as the measure, but with response rate the indications are not clear.

It is not possible to compare response rate with response duration in experiment II, but it is demonstrated that human response duration in itself

has quite a degree of reliability and sensitivity. The duration gradually and consistently decreased over the 18 sessions for group C. Group E's performance would have followed this very closely, but for the introduction of the reaction time task, which produced dramatic changes in duration.

It may be argued that since the variables producing the changes in duration in the above experiments were external, whereas the pharmacologists and chemists are interested in manipulating internal variables (by injecting drugs, etc.), is it possible to generalize from one study to the other? There is some evidence showing that schedules of reinforcement, which are especially sensitive and reliable in relation to external changes, have the same characteristics in relation to internal changes (Sidman, 1960; Ferster and Skinner, 1957). Therefore, response duration should prove to be as good a measure of behavior when used in drug studies as it was in the above experiments. In support of this, some work has recently been started measuring response duration in pigeons (Hingtgen and Aprison, 1963). The early data suggests that in using both response duration and response rate, a more reliable and sensitive measure of behavior is obtained than when either is used alone.

CHAPTER X

SUMMARY AND CONCLUSIONS

Two independent experiments were designed to furnish additional information about response duration so that this measure of behavior could eventually be used in developing more sensitive schedules of reinforcement.

Experiment I: Sixteen albino rats were trained to press a bar for water reinforcement on a force contingency schedule, whereby only bar presses of 15 gm. or over would trigger reinforcement. The average duration of the bar presses (D) and the number of responses (bar presses) were recorded for 44 daily ten minute sessions. After the first 7 days on a 15 gm. force contingency schedule, the animals were divided into four groups, so that the mean Ds were approximately the same for each group. Then 25 more sessions were given during which either a 15, 30, 45, or 60 gm. force was required to press the bar and obtain reinforcement. Following this, the final 12 sessions were given on a 15 gm. force contingency schedule. The results indicated that (a) an increase in the force contingency schedule is followed by a significant decrease in D; (b) the larger the increase in the force schedule, the greater the decrease in D, until the lower limit is reached; (c) the D remains decreased as long as the animals remain on the increased force schedule; (d) a decrease in the force schedule is followed by a significant increase in D; (e) the larger the decrease in the force schedule, the greater the initial

increase in D, followed by a gradual return to the normal D; and (f) the animals appeared to learn the reinforcement limitations of the apparatus and approached a more effecient level of response output, as compared with the original response output.

Experiment II: Twenty-one freshman college males played bingo games during 18 daily individual testing sessions. The subjects obtained the bingo numbers, which were painted on marbles, by pressing a response lever. Playing bingo in the standard way, a total of 50 numbers was given each session (one number for each lever depression). Cash prizes were offered to the winners of the greatest number of games over the 18 session experiment. While the subjects thought the experimenter was recording bingo numbers, response durations of each lever depression were actually being recorded.

After 9 sessions, the subjects were divided into two groups with approximately the same mean response duration. One group played bingo as usual, but the other group for the next 5 sessions had to perform a reaction time task before they could get their bingo number in the previous way. Both groups played bingo in the usual way for the final 4 sessions.

It was concluded that over 18 sessions, human response durations follow a consistent and gradual decreasing trend. In addition, it was found that human response durations can be significantly altered by the performance of a reaction time task immediately before the response duration task. It was further concluded that, while human response durations do not stabilize within 18 sessions, the sensitivity of this measure of behavior is as high as that found in other organisms.

Response duration appears to be a reliable and sensitive measure of behavior in both rats and humans and should be utilized in developing new schedules of reinforcement suitable for research in pharmacology and neurochemistry.

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APPROVAL SHEET

The dissertation submitted by Joseph N. Hingtgen

has been read and approved by five members of the

Department of Psychology.

The final copies have been examined by the director

of the dissertation and the signature which appears below

verifies the fact that any necessary changes have been

incorporated, and that the dissertation is now given final

approval with reference to content, form, and mechanical

accuracy.

The dissertation is therefore accepted in partial

fulfillment of the requirements for the Degree of Doctor

of Philosophy.

_____   _____
Date   Signature of Adviser