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Some effects of fixed interval shock on behavior

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SOME EFFECTS OF FIXED INTERVAL SHOCK ON BEHAVIOR

by

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CHAPTER I

INTRODUCTION

The effects of an aversive event on behavior are varied. They depend on the intensity of the aversive event, the temporal relationship of the aversive event to the response, and the organism's prior experience with the aversive event. In general, if the aversive event is response-produced, it tends to decrease the frequency of the response producing it. If the effect of responding is either to terminate or decrease the frequency of the aversive event, then that response is likely to be maintained at a relatively high level. If the aversive event can be neither produced, terminated, nor avoided, then its effects seem to be mixed, increasing some classes of responding and decreasing others. Increasing the intensity of the aversive event in general reduces any responding which produces that event and increases responding which either terminates or avoids that event. The effects of prior experience with an aversive event on responding are mixed and depend in part on the nature of that prior experience. This study proposes to investigate some of the effects of a response-produced event, sometimes called "punishment," on responding. (For a discussion of the theory, explanation and definition of punishment see Appendix I.)

Recent Research

Punishment in a free operant paradigm (Skinner, 1938) is typically studied by presenting a punishing stimulus, usually an electric shock

(Church, 1969) immediately following a response, usually a bar press in the case of rats, monkeys, humans, etc., or a key peck in the case of pigeons. The response being punished is usually maintained by some schedule of positive reinforcement (Ferster and Skinner, 1957). The measure taken is usually a comparison of the rate or probability of emission of the punished response with the rate or probability of emission of that response prior to the instigation of the punishment contingency. Perhaps the simplest measure of the effects of punishment on responding is simply a comparison of pre-punishment baseline rates with rates obtained when the punishment contingency is in effect. Church (1969) points out, however, that this measure is useful only when the pre-punishment and punishment rates are rather widely divergent. He suggests that for a measure to have maximum sensitivity it must be a combination of the response rate during the treatment and the response rate prior to the treatment. Church proposes that the "suppression ratio" (B/(A+B)) where B is some measure of the punishment rate of responding and A is a similar measure of the pre-punishment rate, as the most sensitive measure of response rate differences.

The research reviewed here will confine itself to free operant studies with infra-human species using electric shock as the punishing stimulus.

In general, the research on the effects of punishment on a free operant response can be divided into four main categories: the effects of varying the intensity and duration of the punishing stimulus, the effects of varying the temporal relationships of the punishing stimulus to the response, the effects of prior experience with the punishing stimulus, and the schedule of delivery of the punishing stimulus.

The Effect of Varying Intensity and Duration of the Punishing Stimulus

Almost all research on the effects of punishment on responding have found decreased response rates as a function of increasing shock intensity (Appel, 1963; Azrin, 1959, 1960; Azrin and Hola, 1966; and Church, 1969). If the punishing stimulus is intense enough, its suppressing effects seem to be irreversible (Azrin and Holz, 1966). Appel (1963) found that the response rates of rats showed no tendency to recover either while the punishment contingency was in effect or following its removal. Azrin (1960), however, found that with pigeons at low and moderate intensities of punishment, after an initial reduction, response rates showed a tendency to recover. At low intensity, the recovery was complete; at moderate levels, the recovery was a partial one. At intense levels of punishment, there was no tendency to recover. Azrin, unlike Appel, found, however, recovery of the response rate following the removal of the punishment contingency, and, in fact, found a compensatory increase following the removal of moderate and severe punishment, with rates gradually returning to pre-punishment base-lines.

Increasing the duration of the punishing stimulus has an effect very similar to increasing the intensity of the punishing stimulus (Church, 1969). Church, Raymond, and Beauchamp (1967) used six durations: 0.00, 0.15, 0.30, 1.00 and 3.00 seconds of .16 ma shock in a group design. Responding showed an orderly increase in suppression as a function of increasing duration. Church further found that the intensity and the duration of the shock combine in a simple fashion to determine the "severity" of the punishment and consequent amount of response suppression.

The Effect of Varying the Temporal Relationship of the Punishing Stimulus to the Response

The introduction of a delay between the punished response and the punishing stimulus reduces the amount of response suppression observed. Camp, Raymond, and Church (1967) found with rats, that the introduction of a delay produced a response suppression pattern very similar to the one observed when shock was noncontingently delivered. Azrin (1956) found no difference, initially, between immediate and non-immediate punishment. Over time, however, response rates showed recovery for the non-immediate punishment condition, while the immediate punishment condition showed none. Kelleher and Cook (1959) found that the introduction of a delay between the response and punishment when used concurrently with positive reinforcement increased rather than decreased responding. Their study, however, required that no responding could occur between the punished response and the punishing stimulus. Given this requirement, if the subjects responded at a rate such that their inter-response time was shorter than the delay requirement, punishment could not be delivered. This makes the punishment contingency somewhat similar to the avoidance schedule described by Sidman (1953).

The Effect of Prior Experience with the Punishing Stimulus

The method of introduction of the punishing stimulus also seems important. Church (1969) found that rats exposed to a gradual increase in shock intensity showed less response suppression to .16 ma shock than did subjects with no prior exposure to shock. Conversely, subjects with prior experience with high intensity shock showed more response suppression at lower shock intensity than did subjects without prior experience with high intensity shock.

The Schedule of Delivery of the Punishing Stimulus

The punishing stimulus can be delivered following every response or it can be delivered intermittently. If it is delivered intermittently, it can be done so either in accordance with a ratio requirement -- i.e., after every Nth response, or it can be delivered in accordance with a temporal requirement -- i.e., the first response to occur after a certain amount of time has elapsed since the last punished response, is punished. There are two types of temporal or interval schedules. The shock can be programmed to occur periodically or at fixed intervals (FI), or it can occur aperiodically or at variable intervals (VI). In general, the effect of presenting the punishing stimulus intermittently is to reduce the amount of response suppression (Azrin and Holz, 1966).

Azrin (1956) examined the response rates of pigeons exposed to a concurrent VI 3' (food) and FI 3' (shock) schedule. He found, after prolonged exposure to this schedule, a pattern of negatively accelerated responding during the inter-shock interval. Azrin concluded that fixed interval shock acts in a way similar to but in the opposite direction from that of fixed interval reinforcement.

Kelleher and Morse (1968), however, exposed squirrel monkeys to a concurrent VI 2' (food) and a FI 10' (shock) schedule. After prolonged exposure to this schedule, positively accelerated rates of responding during the inter-shock interval began to appear. That is, the inter-shock pattern of responding was similar to patterns generated by FI positive reinforcement -- rates immediately following shock were low with an increase in rates as the pre-shock time became shorter.

Azrin found a pattern of negatively accelerated responding during the inter-shock interval. Kelleher and Morse, on the other hand, found a pattern of positively accelerated responding during the inter-shock interval. Several explanations of this apparent conflict in findings are possible:

1. Azrin used alternating stimulus conditions. The response key was blue for two minutes and then orange for two minutes. Reinforcement (food) could occur during either stimulus period. Shock was programmed to occur one minute after the initiation of the orange stimulus period. Estes and Skinner (1944) have shown that a stimulus constantly associated with shock can suppress on-going behavior. Kelleher and Morse did not use a "warning" stimulus. The difference in their findings could be due to the presence of the "warning" stimulus.

2. Following shock Kelleher and Morse programmed a one-minute blackout period. Baron and Trenholme (1971) have shown that responding can be maintained when the effect of that response was the production of a timeout period from an aversive schedule. The facilitatory effect observed by Kelleher and Morse may have been due to the blackout. This alternative is unlikely in that in a later experiment using the same subjects, they discontinued blackout and the positively accelerated pattern of responding persisted. Their findings do not, however,

absolutely preclude the possibility that blackout is necessary for the acquisition of the observed pattern of responding.

3. Kelleher and Morse found that reducing the FI 10' (shock) component to an FI 3' (shock) resulted in severe suppression. The difference in findings might, then, be accounted for in terms of differences in schedule selection.

4. The difference in the pattern of responding may be due to differences in the species.

5. In the Azrin study the pigeons were free to move around within the confines of the experimental chamber; the squirrel monkeys in the Kelleher and Morse study were restrained in a primate restraining chair.

6. Smith and Keller (1970) have suggested that the choice of response is critical in maintaining responding in the pigeon when using aversive schedules. The effect of shock is to produce a response which is directly incompatible with key pecking (Smith, Gustavson and Gregor, 1972). It may be a competing incompatible response which is responsible for the negatively accelerated pattern of responding obtained by Azrin.

7. The parameters of the shock in terms of its duration, its intensity, and its method of presentation were different in the two studies. Azrin (1956) used a 500 msec duration shock of an intensity high enough to suppress all responding when that shock followed every response. Shock was delivered to the sole of the pigeons feet through a grid floor. Kelleher and Morse, on the other hand, used a shock with a 40 msec duration and an intensity of 12.5 ma. The shock was delivered through electrodes attached to the tail. The difference in techniques

of shock delivery could possibly account for the differences in findings.

The positively accelerated pattern of responding obtained by Kelleher and Morse is of further interest in that discontinuing the VI 2' (food) component of the schedule did not result in extinction of the on-going responding; that is, a positively accelerated pattern of responding was maintained by the FI 10' (shock) component. Under a two-component FI 10', fixed ratio 1 (FR 1) schedule of shock presentation, positively accelerated responding was maintained during the FI 10' component and suppressed during the FR1 component. Shock in this case seems to be functioning as both a reinforcing and a punishing stimulus, depending on the schedule. Reduction of the shock intensity resulted in a concomitant reduction in responding. Termination of the shock schedule resulted in a pattern of responding similar to that typically found when reinforcement is discontinued. Reinstatement of the shock schedule resulted in an increase in responding. In short, shock seems to be functioning as a reinforcer.

The apparent "paradoxical effect of shock" obtained by Kelleher and Morse is not new. Several investigators (McKearney, 1968, 1969, 1970, 1972; Morse and Kelleher, 1970) have obtained shock-maintained responding. The uniqueness of the Kelleher and Morse findings lies not in the fact that response-produced shock will maintain responding but, rather, in the method by which the shock was introduced. Typically, studies involving paradoxical effects of shock initially shape the subjects to respond with a non-discriminated free operant avoidance procedure (Sidman, 1953). Once stable avoidance responding is obtained, the subjects are shifted to a schedule of response-produced shock. In the Kelleher and Morse procedure, however, the response which produced shock was never maintained using shock as negative reinforcement.

The Kelleher and Morse study has not been replicated. Their findings were unexpected, given the current body of punishment literature. Their findings seem to have large clinical implications for behaviors which are apparently being maintained by schedules utilizing contingent "aversive" stimuli. Given these considerations, an examination of the effects of fixed interval shock on ongoing behavior seems worthwhile.

CHAPTER II

EXPERIMENT I

Introduction

Azrin (1956) and Kelleher and Morse (1968) seem to have produced contradictory findings. Azrin found that FI shock produced a suppression of responding while Kelleher and Morse found a facilitatory effect. Several possible explanations for the difference in findings have been offered. The purpose of this study is to examine the effects of FI shock on responding.

Method

Subjects. Three male rats, Holtzman strain, approximately 150 days old at the beginning of the experiment and with prior experience in a modified Hebb-Williams water maze (Cowley and Griesel, 1962) were used. The subjects were maintained at 80% plus or minus 5% of their *ad lib* weight, by controling their access to water. They were housed in separate cages and had free access to food.

Apparatus. The experiment was conducted in a standard operant conditioning chamber designed for rat use. The dimensions of the chamber were 25.4 cm wide by 35.6 cm long by 25.4 cm high. All four walls were made of stainless steel. The ceiling was clear plexiglass to allow viewing of the subjects, and was hinged to provide access to the chamber. The floor of the chamber was a shock grid made of tubular stainless steel 1.5 cm in diameter and running paralled to the long axis of the chamber, as described by Dinsmoor (1958). The manipulandum and water dipper were located on one of the walls perpendicular to the long axis of the chamber. The water dipper, a standard Lehigh Valley rat dipper model 1356, was located on the midline of the wall 3.8 cm above the floor. The manipulandum was located 7.6 cm to the right of the water dipper and 5.1 cm above the floor. It was a rod of stainless steel 0.5 cm in diameter and it protruded 1.9 cm into the box. A downward deflection of 0.6 cm with a force of 15 gr resulted in a microswitch closure and an audible click. Directly above the manipulandum (7.6 cm from the floor) was located a 24 volt house light. This light remained on during all sessions. The entire experimental space was housed in a sound and light attenuated chamber. White noise was present in the room housing the attenuation chamber at all times.

Programming and recording was done with standard solid state and electro-magnetic programming and recording equipment located in another room. A high speed paper tape perforator which produced computer compatible paper tape for computer analysis was used to acquire data.

Procedure. Initial training consisted of shaping the subjects to bar press for 0.04 cc of water. Access to the water was limited to four seconds per presentation. Once the response had been shaped the subjects were placed on a constant probability variable interval one minute (VI 1') schedule of reinforcement for access to water as described above (Catania and Reynolds, 1968). This schedule was chosen because it provides a baseline of high stable rates against which the effects of the punishment procedure can be measured. All three subjects were exposed to this schedule for at least 15 days. At the end of this period the punishment contingency was introduced.

Punishment was foot-shock delivered through the grid floor. The electric shock was generated by a CJA constant current shock source and was scrambled by a Davis Scientific Instruments shock scrambler, model 255. The shock was initially introduced at a very low intensity, 0.1 ma, and was gradually increased over the first ten days of the shock condition to an intensity of 0.8 ma. This was done to insure that the animals did not completely suppress, as some investigators have indicated happens when high-intensity shock is suddenly presented (Church, 1969). The shock duration was always 0.25 seconds.

For subjects 5 and 7 shock was delivered contingent on the first response to occur following a fixed interval of three minutes (FI 3'), and for subject 9 shock was delivered following a fixed interval of five minutes (FI 5') since the last shock. If the subjects failed to collect a programmed shock, the shock was delivered non-contingently, 20 seconds after the inter-shock interval had terminated. At no time could a single response produce both shock and reinforcement, nor could a response emitted within three seconds of a shocked response produce reinforcement. This was done to insure that shock could not become a discriminative stimulus for reinforcement.

These values of the FI shock component were chosen for several reasons. Keller (1972), in a pilot study, found no detectable changes in response rates of rats exposed to a FI 10' schedule of 2.0 ma contingent shock. The FI 3' and FI 5' shock schedules provide either:

(1) a schedule of shock presentation that has resulted in response decrements in both pigeons and squirrel monkeys or (2) a schedule intermediate to one shown to have a suppressing effect on squirrel monkeys and pigeons, and one which has no apparent effect on rats.

The subjects were exposed to this concurrent VI 1' for water reinforcement, FI 3' or 5' shock schedule from day 16 to day 75. On day 75 the shock intensity for subjects 5 and 7 was reduced to 0.5 ma. Subjects 5 and 7 were run for another 40 days at this value. Subject 9 was continued at 0.8 ma. After 115 days the VI 1' reinforcement schedule was discontinued and the subjects were run for another 15 days with only the FI shock schedule in effect.

The average length for all sessions was 55 minutes.

Results

Figure one shows in five-day blocks the average response rate per minute for each subject across the entire experiment. All three subjects showed an overall suppression of responding during the punishment condition over the rates observed during the pre-punishment baseline condition. Subjects 5 and 9 began to show a reduction in response rates during the first five-day block following the introduction of the shock contingency. Subject 7 showed an initial increase in responding during the first two five-day blocks. By the fourth five-day block, however, all three subjects showed a maximum reduction in response rates. Beginning with block five all three subjects showed a slow irregular recovery of response rates. In no case, however, prior to the end of block 15 did response rates recover to the pre-punishment level. Following the reduction of shock intensity on session 76 for subjects 5 and 7, subject 5 showed a recovery of its response rate to a level greater then that observed during the pre-punishment period; subject 7, however, showed a marked decrease in its response rates. During the last 15 days of the experiment when only the FI shock component was in effect, all subjects showed a reduction in responding and, ultimately, extinction of the response.

Table 1 shows the suppression ratio for the first five-day block, the block for the five days showing the greatest suppression, the five-day block prior to the reduction of shock intensity for subjects 5 and 7 and the last five-day block of the shock condition. The suppression ratios were computed by dividing the response rate per minute for the block (B) by the average response rate per minute for the block immediately preceding the instigation of the punishment procedure (A) plus block B.

$$B/(A+B)$$

An examination of responding for all three subjects showed a clear inter-shock pattern of negatively accelerated response frequency. That is, the frequency of responding tended to be high immediately following shock and to taper off as time for the delivery of the next shock approached. The frequency of responding during the inter-shock interval was examined in 10 second periods. Figure 2 shows the percentage of the total number of responses made in each post-shock 10 second period for the first day of the punishment condition for subjects 5 and 7. Figure 3 shows similar data for subject 9. The heavy straight line at 5.5% on figure 2 and at 3.3%

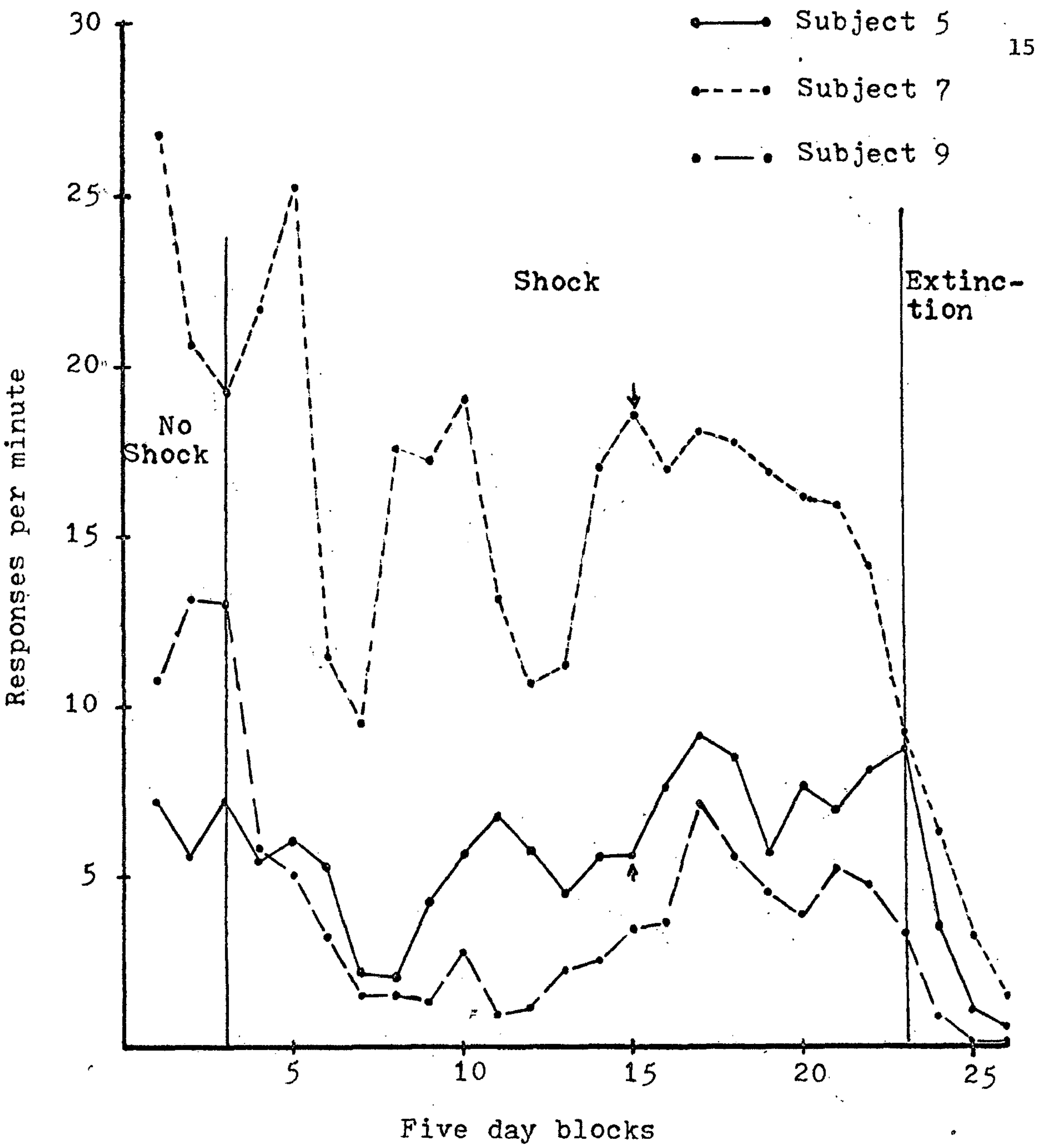

Fig. 1 Shows the average responses per minute considered in five day blocks across the entire study for all three subjects. Arrows indicate the point at which the shock intensity was reduced for subjects 5 and 7.

Table 1

Suppression Ratio

Subject	Day	1-5	16-20	56-60	96-100
5		.43	.23	.44	.55
7		.53	.33	.49	.32
9		.31	.10	.21	.20

Shows the suppression ratio in five-day blocks for the first five days of shock, the block for the five days showing the greatest suppression, the five-day block prior to the reduction of shock for subjects 5 and 7, and the last five-day block of the shock condition, for all three subjects.

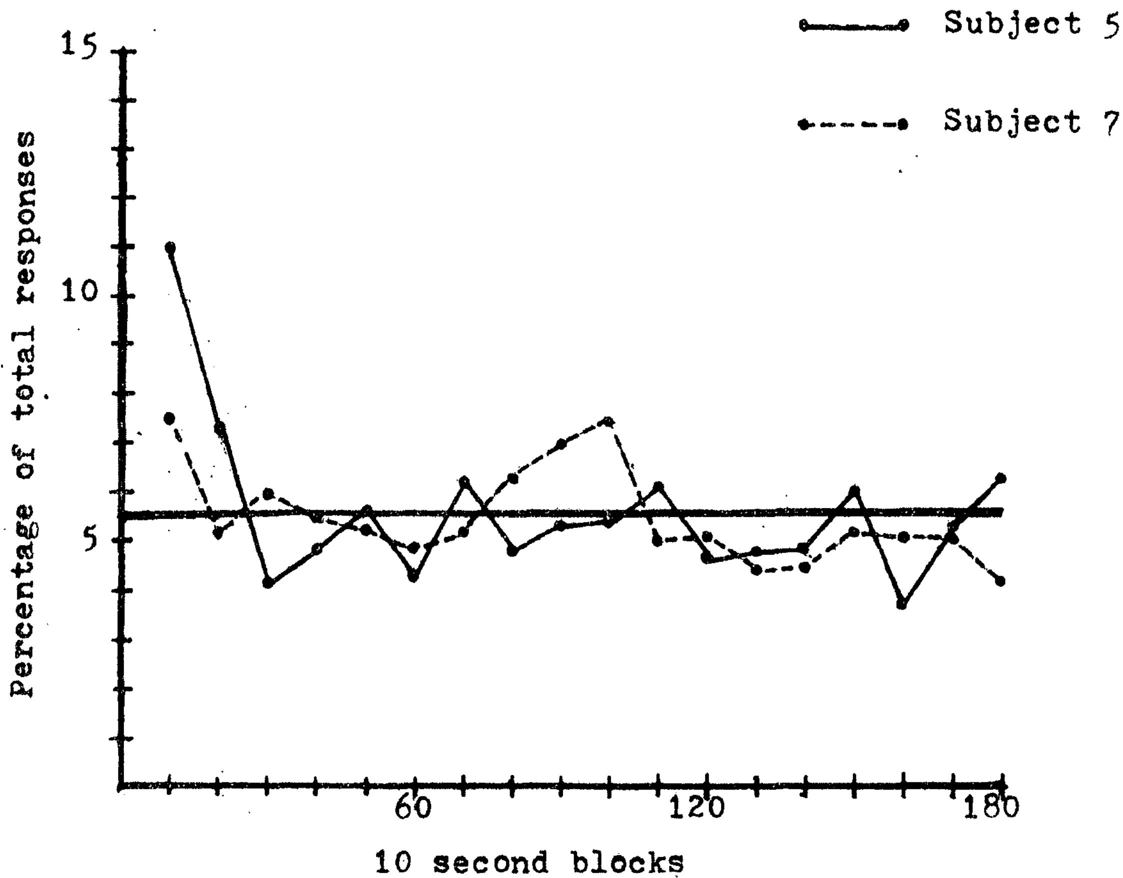

Fig. 2 percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day one of the shock condition for subjects 5 and 7. The heavy line at 5.5% is the expected percentage of responses given no effect from the shock.

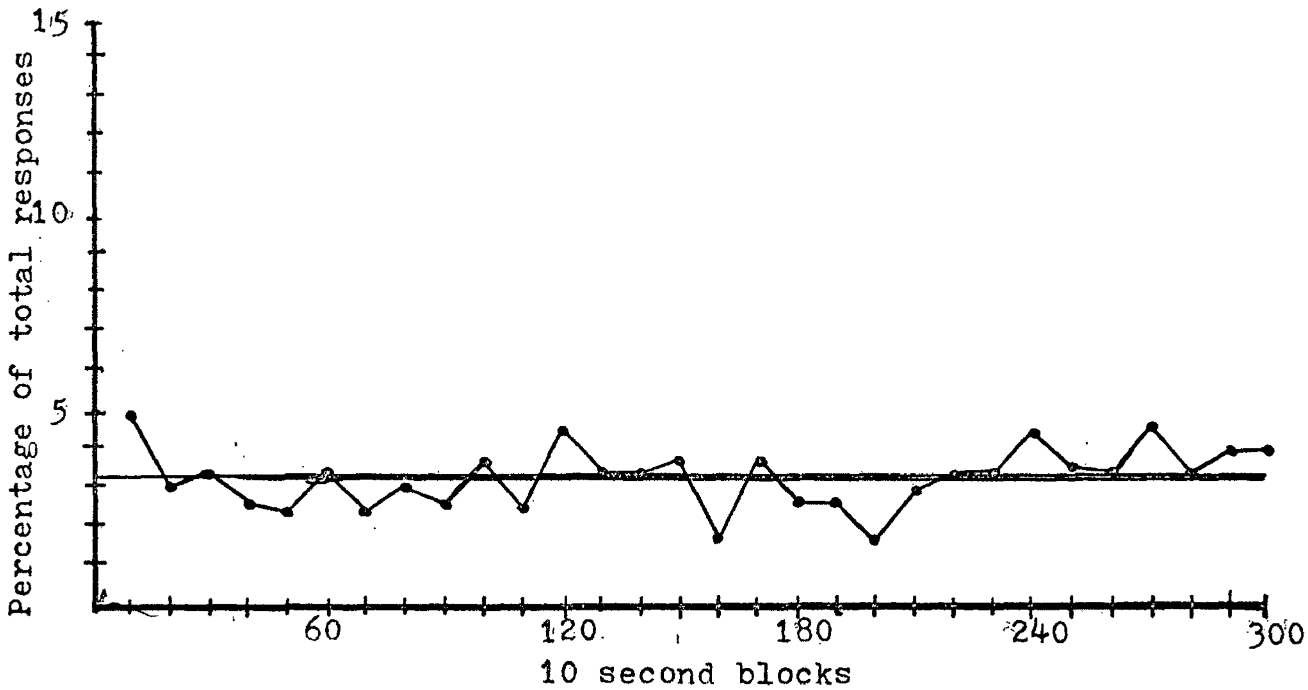

Fig. 3 Percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day one of the shock condition for subject 9. The heavy line at 3.3% is the expected percentage of responses given no effect from the shock.

on figure 3 is the expected percentage of responses for each 10 second period during the inter-shock interval given that there was no differential in response frequency during the interval. None of the three subjects showed a systematic variation from the expected value, although subject 5 showed some elevation of responding during the first 10 second period following shock.

By day 20 of the shock condition, the final day of the five-day block showing the lowest overall response rate, a clear-cut pattern of responding had begun to emerge.

Subject 5 emitted a high percentage of its responses in the first two 10 second blocks immediately following shock. A sharp decline in responding followed this initially high response frequency to a point such that the response frequency in the blocks immediately preceding shock were much lower then the expected value, given that shock was having no differential effect.

Subjects 7 and 9 emitted close to the expected percentage of responses during the first 10 second block following shock and a large increase in responding during the period 10 to 20 seconds following shock, (block 2). This increase was followed by a sharp reduction in response frequency in the subsequent blocks. This decrease was to a level well below expected for subject 7. Subject 9, although emitting responses substantially above expected during the period immediately following shock did not show a clear pattern of response frequencies below expected prior to shock until day 60 of the shock condition. (See Appendix IIa).

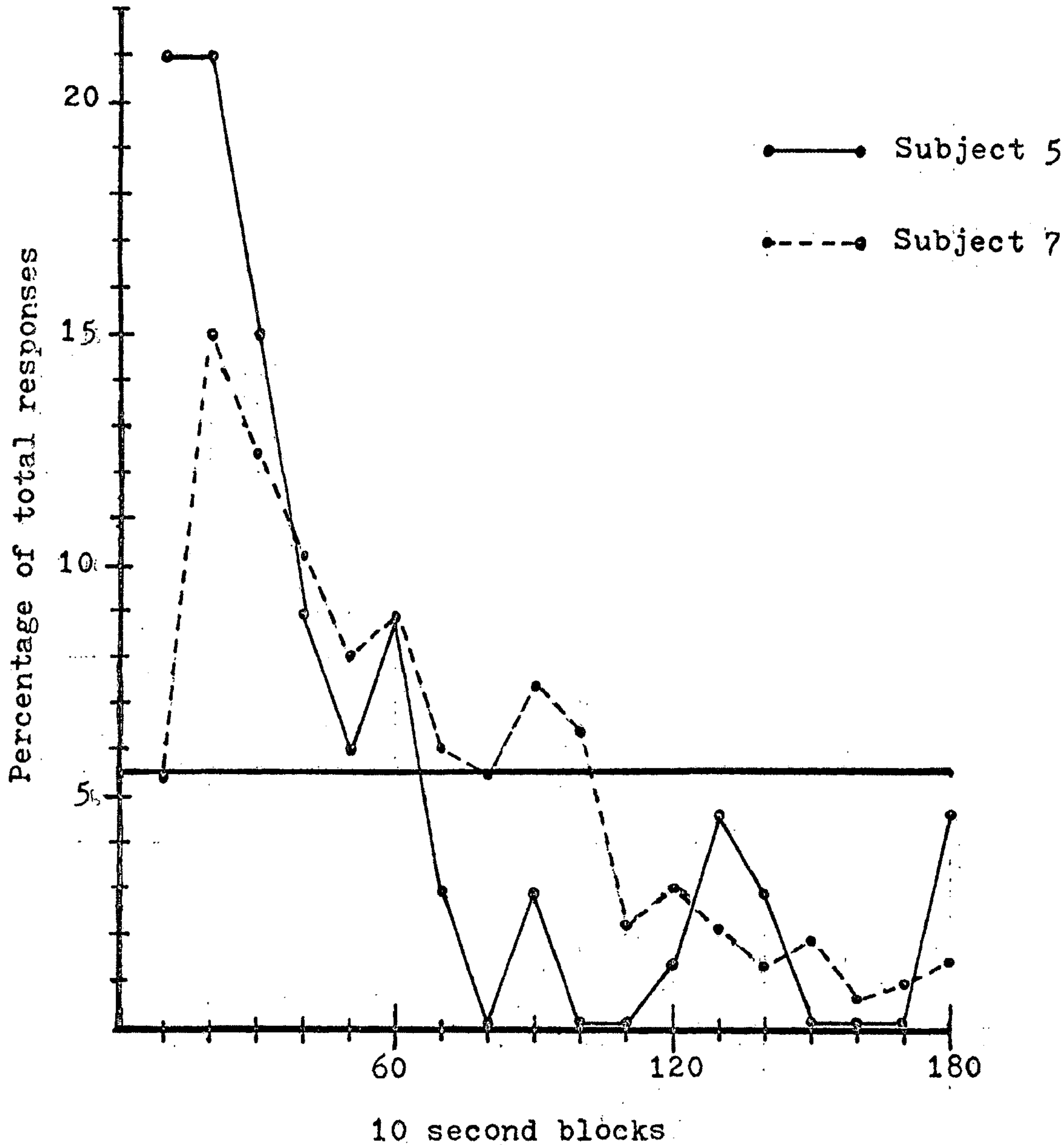

Fig 4 Percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day twenty of the shock condition for subjects 5 and 7. The heavy line at 5.5% is the expected percentage of responses given no effect from the shock.

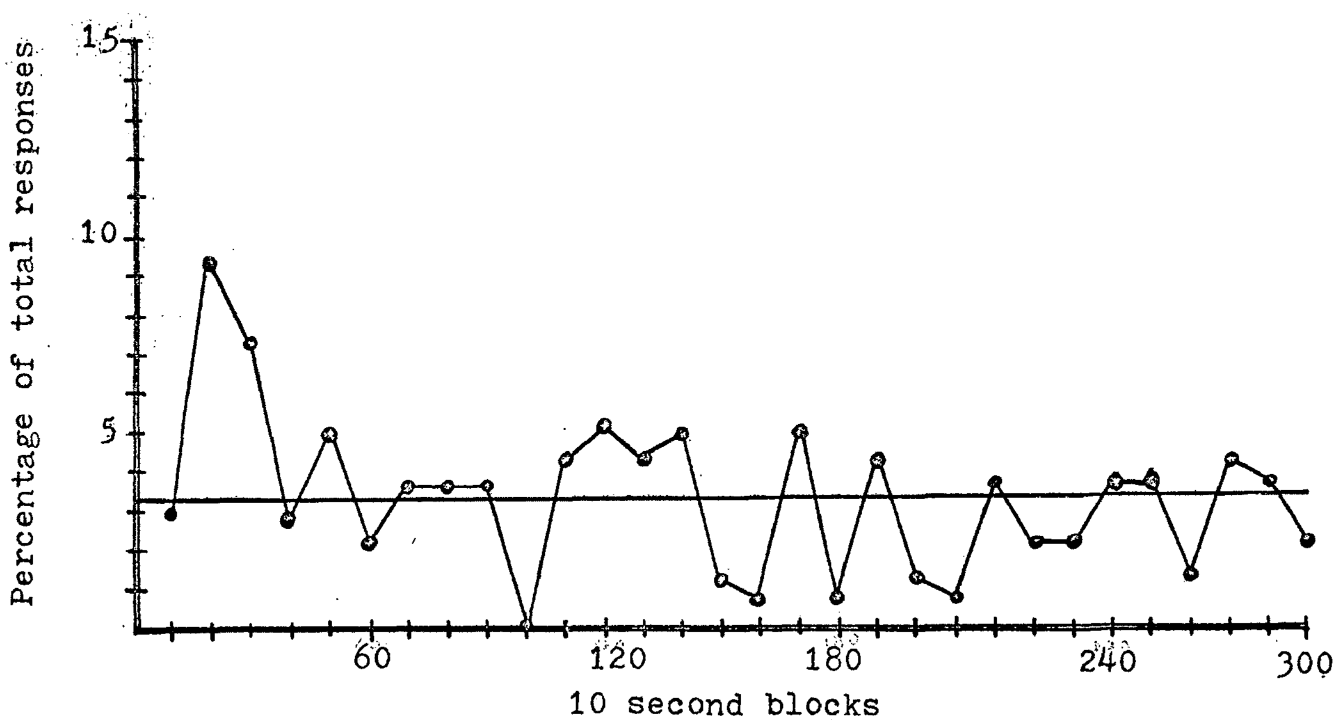

Fig..5 Percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day twenty of the shock condition for subject 9. The heavy line at 3.3% is the expected percentage of responses given no effect from the shock.

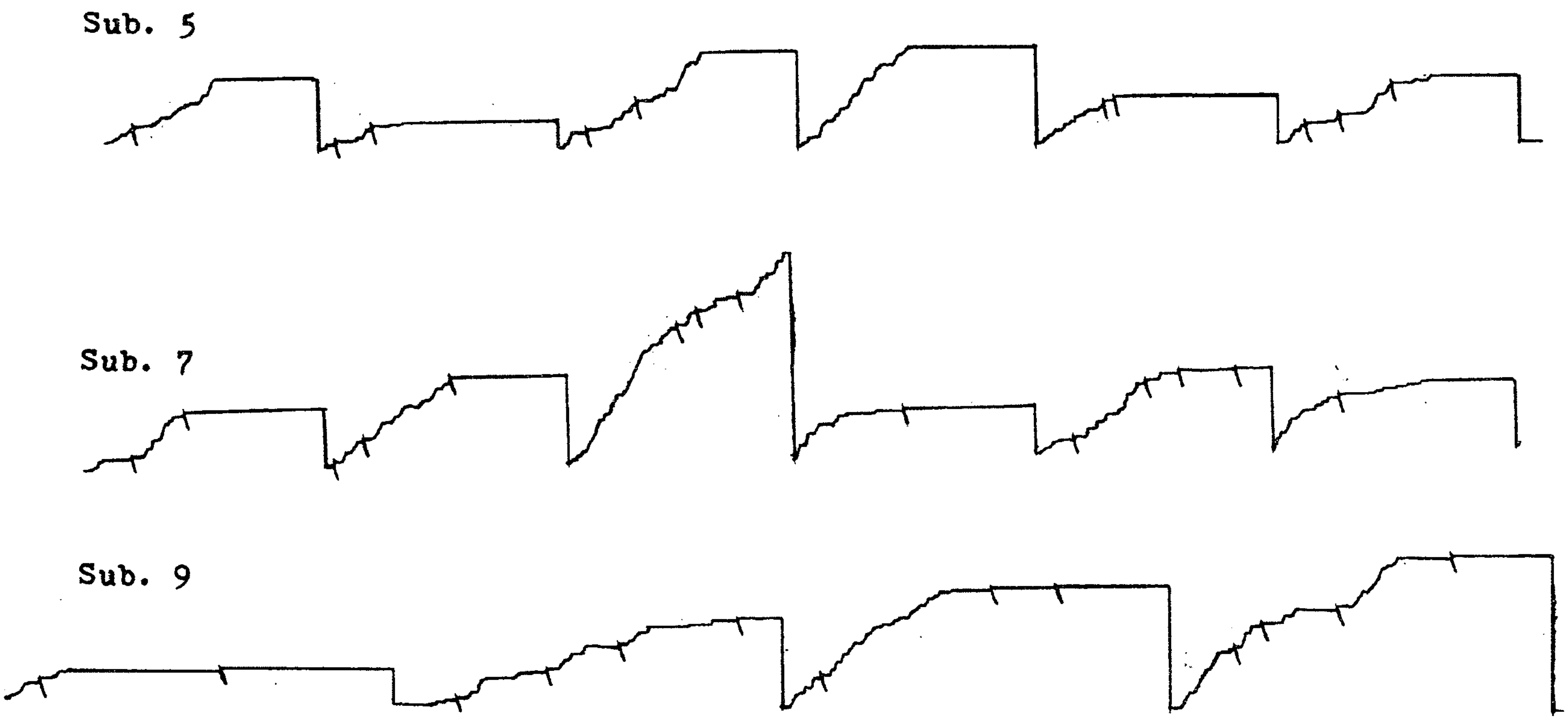

Fig. 6 Shows selected cumulative records for subjects 5, 7, and 9.

By day 30 of the shock condition subject 5 also showed an initial post-shock response pattern similar to the one just described for subjects 7 and 9. (See Appendix IIb)

All three subjects showed a persistence of the pattern of responding just described from day 20 of the shock condition throughout the entire course of that condition and into the extinction condition. (See Appendix IIc)

Figures 4 and 5 indicate that the reduction in response rates across the inter-shock interval was a gradual and continuous process. An inspection of the cumulative records indicates that the response pattern is better described as an initial high stable response rate immediately following shock, followed by an abrupt cessation of responding. Figure 6 is comprised of selected cumulative records for the three subjects. The apparent smooth reduction in responding seen in figures 4 through 6 is probably due to the fact that the subjects responded at a stable rate to some point in time following shock and then abruptly ceased responding almost completely until after the next shock was delivered. It is the different points in time following shock at which cessation of responding occurred for each inter-shock interval which accounts for the apparent smooth reduction.

CHAPTER III

EXPERIMENT II

Introduction

Experiment I showed a clear-cut pattern of negatively accelerated response rates across the inter-shock interval. As no warning stimulus was present in Experiment I for any of the three subjects it would appear that the "warning" stimulus used by Azrin does not account for the negatively accelerated response pattern observed both in the Azrin study and in Experiment I. Kelleher and Morse have indicated, however, that they also have obtained response suppression at inter-shock values of three minutes. They also used a one-minute blackout following shock, which might possibly account for the positively accelerated response rates. With this in mind Experiment II is an attempt to replicate the Kelleher and Morse procedure. Due to species and equipment differences there are some minor procedural differences, primarily in the area of shock intensity and its method of delivery.

Method

Subjects. Three male rats, Holtzman strain, approximately 150 days old at the beginning of the experiment and with no known experimental history were used. The subjects were maintained at 80% plus or minus 5% of their ad lib weight by controlling their access to water. They were housed in separate cages and had free access to food.

Apparatus. The same apparatus used in Experiment I was used in Experiment II.

Procedure. Initial training consisted of shaping the subjects to bar press for 0.04 cc of water. Access to the water was limited to four seconds per presentation. Once the response had been shaped the subjects were placed on a constant probability VI 2' schedule of 0.04 cc of water reinforcement (Catania and Reynolds, 1968).

Each session was divided into cycles consisting of a response period followed by a one-minute blackout period during which responses had no effect, and the VI 2' schedule was interrupted. For subject 10 the first response after a five-minute period had elapsed produced blackout. Subsequent five-minute response periods were timed from the termination of the blackout of the preceding cycle. The procedure for subjects 11 and 12 was exactly the same except that the first response to occur after a ten-minute period had elapsed produced blackout. All sessions were terminated following the completion of the tenth cycle. All three subjects were exposed to this procedure for 12 days.

On day 13, the first response to occur after five minutes for subject 10 and after ten minutes for subjects 11 and 12 had elapsed produced a 1.5 ma foot shock having a duration of 100 msec. Blackout occured for all three subjects immediately following shock. Subsequent cycles were timed from the termination of the blackout of the preceding cycle. Again all sessions were terminated following the completion of the tenth cycle. The subjects were not run from day 16 through day 21, to allow time for recovery from the complete suppression brought about by the 1.5 ma shock. On day 22 the same schedule as described for sessions 13 through 15 was reintroduced. The subjects were not run on day 25, again to allow for recovery, and on day 26 the same schedule as described for sessions 1 through 12 was reintroduced. On day 28 for subjects 10 and 12, and on day 30 for subject 11, the shock condition was again instigated. The shock level was initially set at 0.1 ma and then raised 0.1 ma per day until a shock level of 0.5 ma was reached. This level of shock intensity was used through the rest of the experiment. On day 43 shock was again discontinued for five sessions and then reinstigated on session 48. Following the session on day 52 the experiment was terminated.

Results

Figure 7 shows the average responses per minute for all three subjects during each session across the entire experiment. Response rates for all three subjects during this experiment were highly variable, however the direction of change for all three subjects for each phase of the experiment was the same. Consequently the data on the rate of responding is averaged across the three subjects. The average response rate for all three subjects during session 12, the last session prior to the instigation of the punishment contingency, was 6.7 responses per minute. By day 18, the last day in which the 1.5 ma shock contingency was in effect the average response rate for the three subjects had fallen to 0.0 responses per minute. Following the reduction of shock intensity to 0.0 ma on day 26, response rates showed an almost immediate rise to a level comparable to pre-punishment rates. When shock was reintroduced at low intensity (0.1 ma) and then over the course of several days increased to 0.5 ma, the subjects again showed a reduction in response rates such that by session 34 the average response rate for all three subjects was 0.3 responses per minute. Response rates then showed a gradual, irregular increase, reaching a level of 3.0 responses per minute on day 42. Beginning with day 43 shock was discontinued, and response rates showed an immediate increase to 8.3 responses per minute on day 47. Following the reintroduction of the shock contingency on day 48, response rates showed an immediate decrease.

An examination of individual subject's response rates across the inter-shock interval for day 52 showed a pattern of negatively accelerated response rates for subjects 11 and 12. Subject 10, while showing an overall suppression, showed no systematic variation from either pre-punishment patterns of responding or from the expected pattern, given that neither blackout nor shock had any differential effect on responding.

Figure 8 shows the distribution of responses in one-minute blocks across the inter-shock interval for subject 10. The heavy line at 20% is the expected percentage of responses emitted in that block given that the blackout and/or shock had no effect. The dashed line is the percentage of responses emitted in each one-minute block during session 12, the last session prior to the initial instigation of the shock contingency. The solid line is the percentage of responses emitted in each one-minute blocks during session 52, the last day of the experiment. In neither session 12 nor 52 did the obtained frequency of responding differ significantly from the expected.

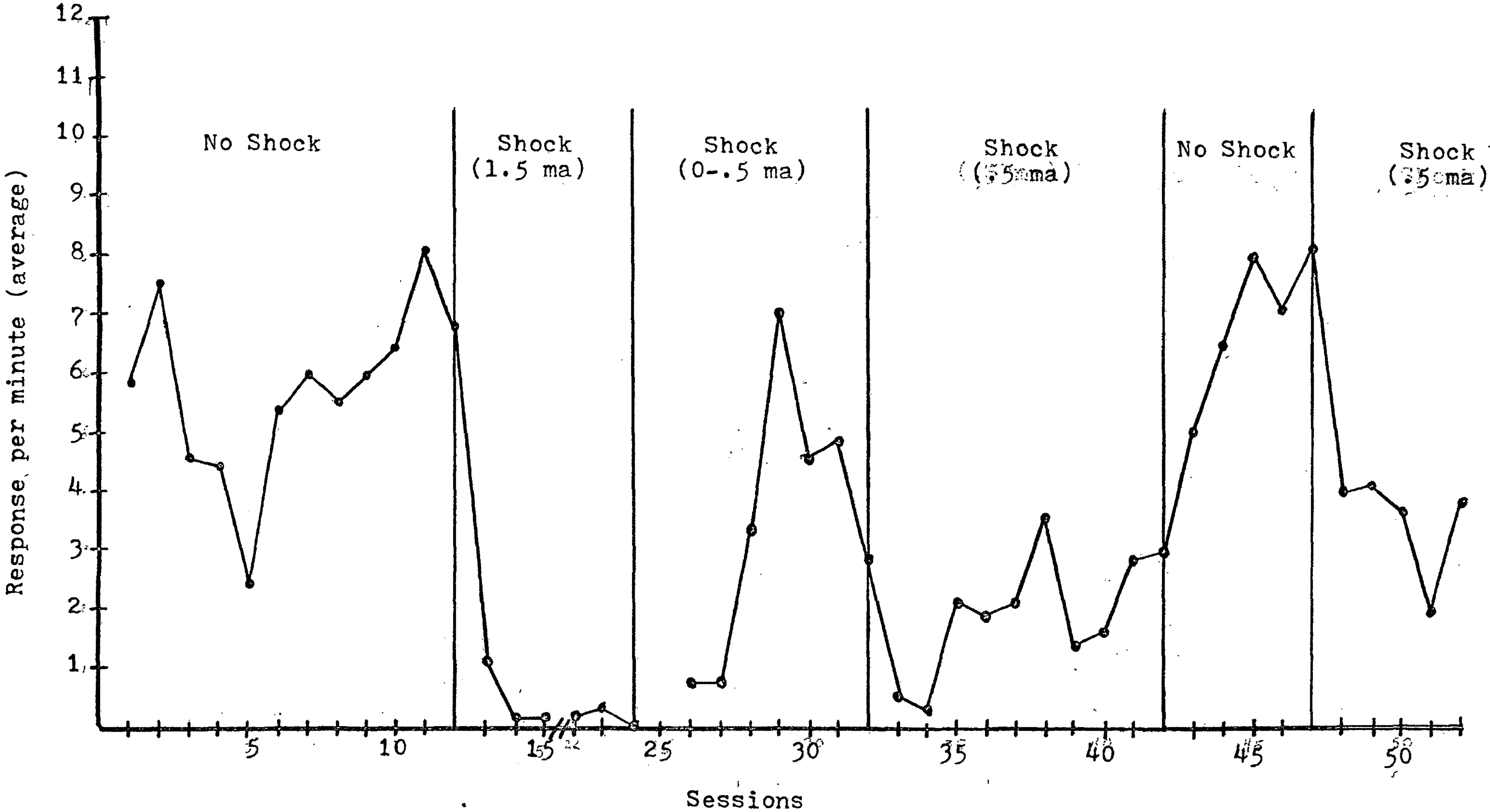

Fig..7 The average responses per minute for all three subjects across the entire experiment.

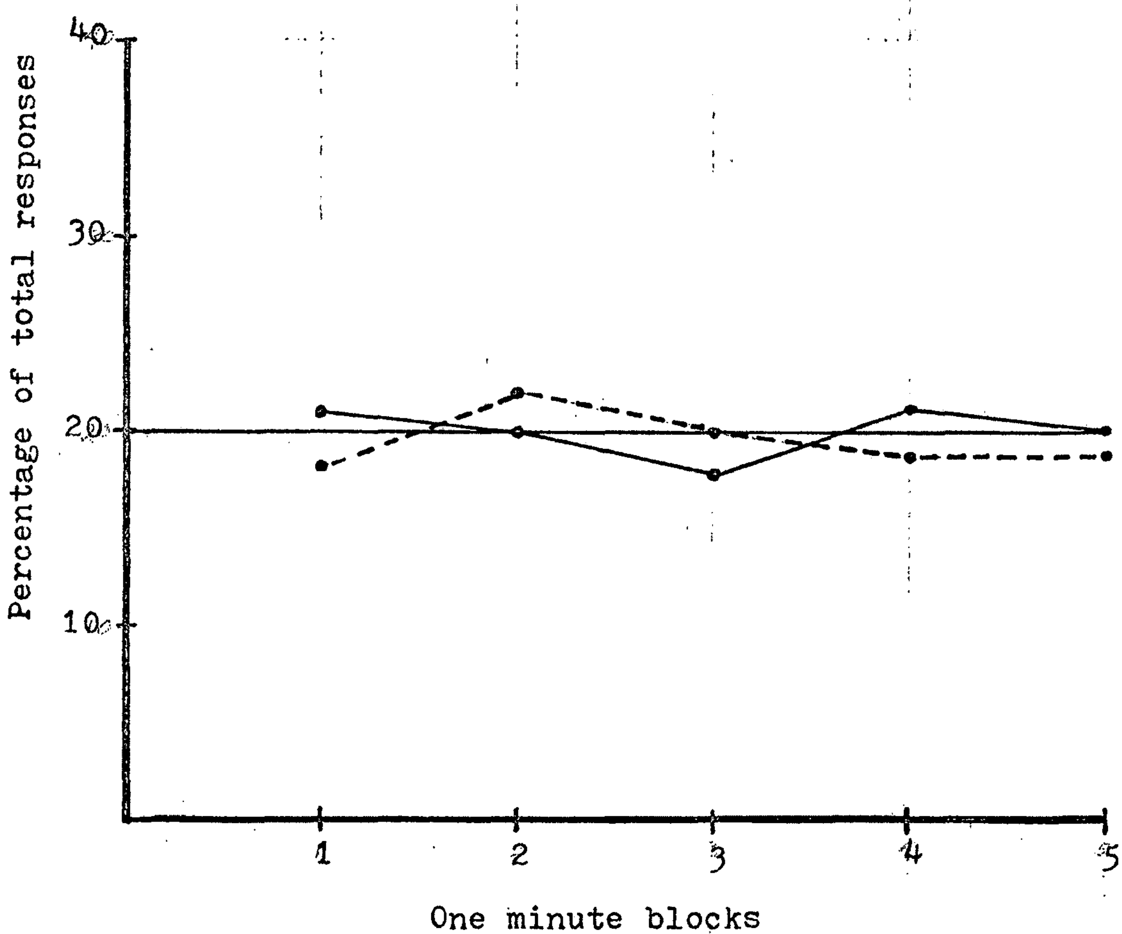

Fig. 8 Broken line shows the percentage of responses made in each one minute block across the cycles for subject 10 on day 12. The solid line shows the percentage of responses on day 52. The heavy line at 20% is the expected percentage of responses given that blackout and/or shock had no effect.

Figures 9 and 10 show similar data for subjects 11 and 12. In this case, however, the expected percentage of responses for each one-minute block is 10%. Both subjects 11 and 12 emitted a high percentage of responses in the first block following blackout. In the following blocks the percentage of responses fell to levels generally below the expected level.

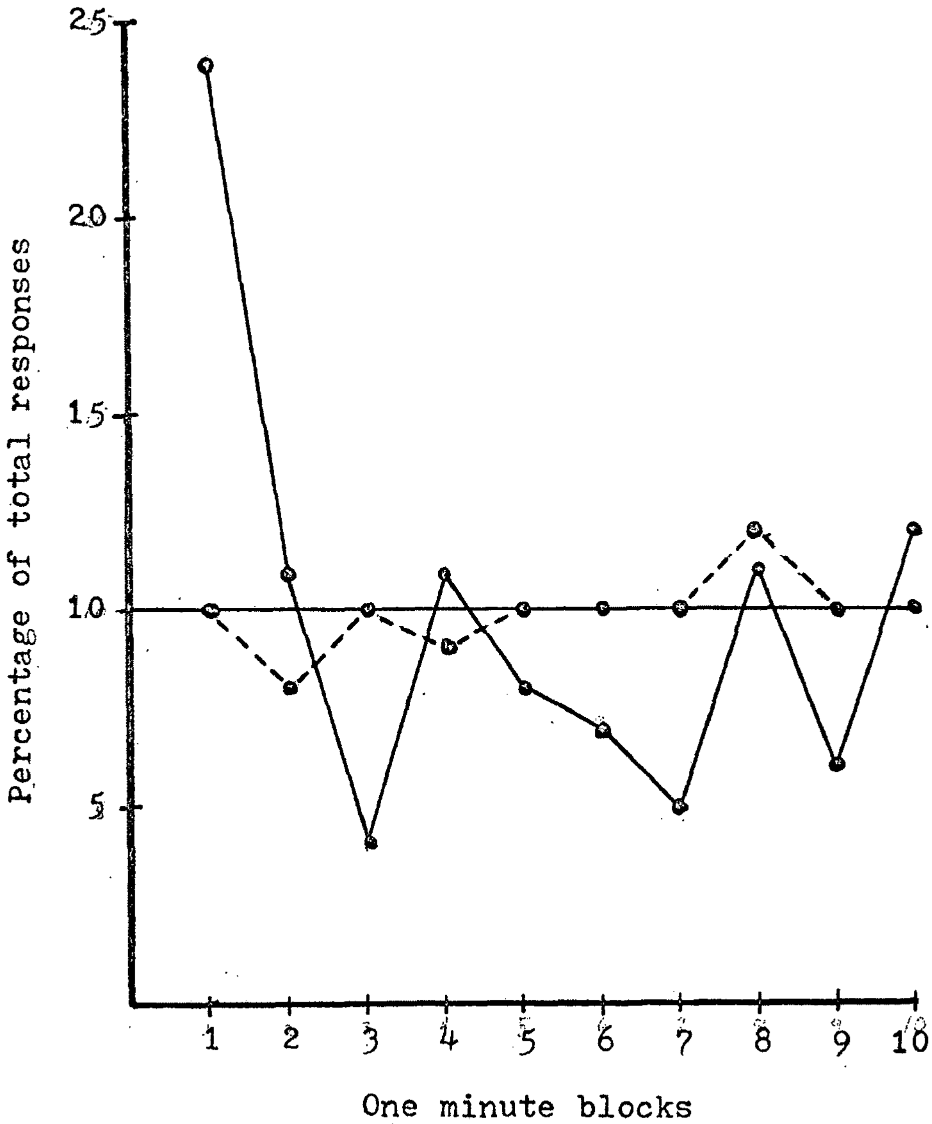

Fig. 9 Broken line shows the percentage of responses made in each one minute block across the cycles for subject 11 on day 12. The solid line shows the percentage of responses on day 52. The heavy line at 10% is the expected percentage of responses given that blackout and/or shock had no effect.

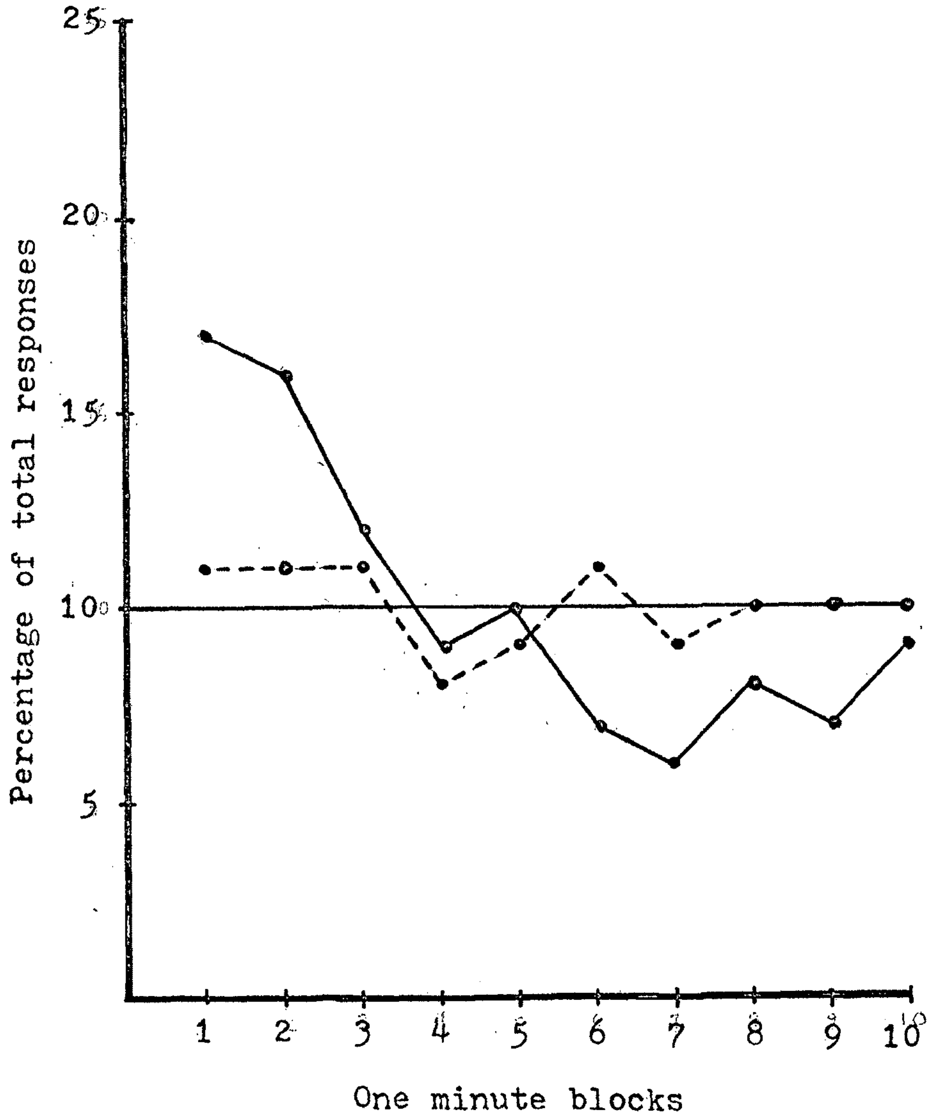

Fig. 10 Broken line shows the percentage of responses made in each one minut block across the cycles for subject 12 on day 12. The solid line shows the percentage of responses on day 52. The heavy line at 10% is the expected percentage of responses given that blackout and/or shock had no effect.

CHAPTER IV

DISCUSSION

In all six subjects, fixed interval shock suppressed overall response rates below the levels observed during the pre-punishment condition. In subjects 5, 9, 10, 11, and 12, following an initial suppression, response rates showed a slow irregular increase across the duration of the punishment conditions. Only in the case of subject 5 did punishment response rates exceed those observed during the pre-punishment period. In the case of subjects 10, 11, and 12 discontinuing the punishment contingency resulted in an immediate increase in response rates to a level similar to those observed during the pre-punishment period.

All but subject 10, after prolonged exposure to the fixed interval punishment schedule, showed a pronounced pattern of negatively accelerated response rates across the inter-shock interval. Several explanations of this negative acceleration are possible.

Competing Response Hypothesis

Sidman (1953) found that responding could be maintained by an avoidance schedule in which shock was programmed to periodically occur, unless the subject responded. If the subject responded, the onset of the next shock was delayed a specific length of time from the last response. If the response rate of the subject was sufficiently high all shocks could be avoided.

Anger (1963) pointed out that subjects on this avoidance schedule showed a response pattern indicating a discrimination of the passage of time since the last shock or response. As time since either the last shock or response becomes greater (that is, time before the onset of the next shock gets less) the probability that the subject will emit an avoidance response becomes greater. Anger suggested that this schedule has associated with it time correlated stimuli. The stimuli associated with long times since the last response or shock -- that is, stimuli occuring near in time to the onset of the next shock -- become conditioned aversive stimuli. Stimuli associated with relatively short times since the last response or shock are relatively neutral. A response then, made near the time of onset of the next shock allows the subject to escape the relatively aversive stimuli associated with that shock, returning the subject to the relatively neutral stimulus conditions associated with short post-response times.

A competing response hypothesis similar to the one suggested by Mowrer (1960) (see Appendix I) utilizing a modification of Anger's conditioned aversive temporal stimuli is a possible explanation of the response patterns observed in both experiments I and II. Stimuli, and particularly response-produced stimuli, associated with the punished response become classically conditioned stimuli eliciting fear. Those stimuli occuring near in time to the punished response elicit the most fear. Any instrumental response which avoids this fear will be learned. All instrumental responses other than the punished response will accomplish this. Consequently, as the time prior to the onset of the next shock gets shorter there is an increase in the aversiveness of the stimuli associated with responding, and, consequently, an increase in responding which will avoid these aversive stimuli, that is, an increase in all responding other than the punished response.

Law of Effect Explanation

Azrin (1956) suggested that the negatively accelerated response rates he observed could be accounted for within the law of effect. He concluded that fixed interval shock acts in a way similar to but in the opposite direction from, that of fixed interval reinforcement. A similar explanation can be given for the negatively accelerated inter-shock response rates observed for subjects 5, 7, 9, 11, and 12.

Schneider (1969) observed in subjects exposed to fixed interval reinforcement schedules for long periods of time an inter-reinforcement response pattern characterized as "break and run," rather than the more characteristic "scalloping" pattern described by Ferster and Skinner (1957). "Break and run" is a response pattern in which response rates during the initial part of the inter-reinforcement interval are essentially zero, followed by an abrupt shift to a high stable response rate which terminates with reinforcement. Subjects in experiment I after prolonged exposure to fixed interval punishment developed a response pattern of relatively high rates during the initial part of the inter-shock interval, followed by an abrupt cessation of responding -- a pattern which might be characterized as a "run and break" pattern. This apparent symmetrical relation between the "break and run" pattern observed in fixed interval reinforcement by Schneider and the "run and break" pattern observed in experiment I gives further credence to Azrin's characterization of fixed interval punishment in terms of the law of effect.

Evaluating the Relative Merits of the Alternative Explanations

In evaluating the relative merits of a competing response explanation of the data versus a law of effect explanation, several points should be kept in mind. First, a competing response explanation is open to the objections to this kind of theorizing raised by Rachlin and Herrnstein (1969) as discussed in Appendix I of this paper. Second, the response pattern observed in experiment I does not seem compatible with a competing response explanation. It would be expected that as the stimuli associated with the punished response become increasingly aversive the tendency to engage in responses incompatible with the punished response would become progressively greater, resulting in a smooth negative acceleration across the inter-shock interval. This was not the case; response rates while the subjects were responding were high and relatively stable, followed by an abrupt shift to non-responding. Third, the shift from responding to non-responding typically occurred relatively early in the inter-shock interval a time during which stimuli should be relatively neutral.

A law of effect explanation, on the other hand, has the disadvantage of explaining fixed interval punishment as acting in a way similar to but in the opposite direction from, that of fixed interval reinforcement, a process which is itself poorly understood.

Failure to Support

Perhaps the most interesting finding in this study is the failure to replicate the findings of Kelleher and Morse (1968). In the introduction several suggestions were offered as possible explanations for the apparently contradictory findings of Azrin and those of Kelleher and Morse.

1. It was suggested that the presence of an extroceptive "warning" stimulus which was constantly associated with shock might be responsible for the suppression observed by Azrin. However, experiment I did not utilize a "warning" stimulus, and negatively accelerated response rates were observed.

2. Following shock, Kelleher and Morse programmed a one-minute blackout period, possibly accounting for the positively accelerated response rates they observed in their experiment. However, at no time during experiment II was a positively accelerated pattern of responding across the inter-shock interval observed. This was true for the initial 12 days of the experiment, during which each cycle was terminated by blackout only, as well as those days when a cycle was terminated by both shock and blackout. On the final day of the punishment condition, the inter-shock response pattern showed a tendency toward negative acceleration for two of the three subjects. The positive acceleration observed by Kelleher and Morse was probably not due to the presence of blackout.

3. Suppression of responding and negatively accelerated response rates across the inter-shock intervals was obtained for all interval values used (i.e., FI 3', 5', and 10') eliminating the possibility that

the different patterns of responding observed by Azrin and in this study from the one observed by Kelleher and Morse was due to the value selected for the inter-shock interval. (There is, however, the remote possibility that an interval longer than 10 minutes is necessary to obtain the effects obtained by Kelleher and Morse in both rats and pigeons.)

4. It was suggested that the key peck utilized by Azrin was incompatible with a pigeon's unconditioned response to shock, and the effect of shock was to produce a conditioned response which was directly incompatible with key pecking, accounting for the negatively accelerated response rates observed by Azrin. However, a bar press for a rat is not incompatible with the rats' unconditioned response to shock, and negatively accelerated rates were still observed.

Three other procedural differences between the Azrin study and the one of Kelleher and Morse were indicated as being possible sources of differences in the findings.

1. The parameters of the shock in terms of its duration, its intensity, and its method of presentation were different in the two studies. Azrin used a 500 msec duration shock of intensity high enough to suppress all responding when that shock followed every response. Shock was delivered to the sole of the pigeon's feet through a grid floor. Kelleher and Morse, on the other hand, used a shock with a 40 msec duration and an intensity of 12.5 ma. The shock was delivered through electrodes attached to the tail. Both experiments I and II used foot shock. The difference observed between the findings of Azrin and those obtained in experiment I and II and those obtained by Kelleher

and Morse may be due to either differences in shock duration and intensity, or it may be due to the method of shock delivery.

2. In the Azrin study and in both experiments I and II, the subjects were free to move around within the confines of the experimental chamber. The subjects in Kelleher and Morse's study were restrained. Free versus restrained subjects is a possible explanation for the failure to replicate the Kelleher and Morse study.

3. Kelleher and Morse used squirrel monkeys in their study. The Azrin study and experiments I and II utilized infra-primate species as subjects. The difference in findings could be due to a species difference.

It is not possible, however, from experiments I and II to evalute these explanations as possible sources of the difference in findings between those of Azrin and experiments I and II and those of Kelleher and Morse.

Two major observations can be drawn from the results of experiments I and II. First fixed interval shock, even with relatively long inter-shock intervals is effective in suppressing responding. Second, a pattern of suppression characterized by high post-shock rates with an abrupt shift to non-responding at some point during the inter-shock interval, was observed.

CHAPTER V

SUMMARY

Six male rats were exposed to a concurrent variable interval water reinforcement and fixed interval shock schedule. Two values, one and two minutes, for the variable interval schedule, and three values, three, five, and ten minutes, for the fixed interval schedule were used. The effect of blackout following a shocked response for three of the subjects was also evaluated.

All of the subjects showed a decrement in response rates when the fixed interval shock schedule was in force, over the rates observed when the shock schedule was not in force. Five of the six subjects showed clear-cut patterns of negatively accelerated response rates across the inter-shock interval. This negatively accelerated response rate was observed for both values of the variable interval reinforcement schedule and all three values of the fixed interval shock schedule. The blackout contingency following shock seemed to have no effect on the basic response pattern, just described.

The results were consistent with the majority of other findings in this area, but are, however, directly contradictory to the findings of Kelleher and Morse (1968). Several possible explanations of this discrepancy are offered.

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APPENDIX I

THEORY, EXPLANATION, AND DEFINITION OF PUNISHMENT

Early definitions and explanations of punishment tended to be subjective and somewhat anthropomorphic. Thorndike (1913) defined punishment as when "a modifiable connection between a situation and a response is made and is . . . accompanied or followed by an annoying state of affairs, its strength is decreased." He then goes on to define "an annoying state of affairs" as "one which the animal does nothing to preserve, often doing things which put an end to it." In a later formulation, Thorndike (1932) talks about an annoyer as that which "may cause the animal to feel fear or chagrin."

Perhaps the most important aspect of Thorndike's initial definition of punishment, however, is the inclusion of the first explicit formulation of a negative law of effect. Birefly, it was Thorndike's position that an "annoyer" (punishing stimulus) had a symmetrical and inverse effect on responding from that of a "satisfier" (positive reinforcement). Later experimental results (Thorndike, 1932) with human subjects in a verbal learning task in which the word wrong was used as an "annoyer" lead him to reject his initial formulation of the negative law of effect and to propose a competing response hypothesis as an explanation of response decrements during punishment.

Several investigators, Guthrie (1934), Fowler (1971), Skinner (1938), and Estes (1944), have also proposed some form of a competing response hypothesis to explain response decrements due to a punishing stimulus. Mowrer (1960) is a good example of this kind of theorizing. Mowrer's proposal was that stimuli, and particularly response-produced stimuli, associated with the punished response become classically conditioned stimuli eliciting fear. Any instrumental response which avoids this fear will be learned. (Other theories of this general type substitute <u>reduces</u> for <u>avoids</u>, making them escape rather than avoidance theories of punishment.) All instrumental responses other than the punished responses will accomplish this. Reduction in the punished response, then, is due to an increase in responding incompatible with the punished response. These responses are maintained by the avoidance of or escape from conditioned fear elicited by stimuli associated with or produced by the emission of the punished response.

Rachlin and Herrnstein (1969) have pointed out that two-factor theories, such as the one outlined above, have the advantage of being able to explain escape, avoidance, and punishment in terms of one theory; i.e., avoidance and punishment can be seen as simply special cases of escape. However, they contend that whatever may be gained by a two-factor theory in parsimony is out-weighed by the disadvantages. They object to two-factor theories on both theoretical and empirical grounds.

First, if it is possible to postulate an escape theory of punishment, then why not just as conveniently postulate a punishment theory of escape or avoidance; there the basic process is stated in terms of response decrements. It is the contention of these authors that the difference between the two is simply a matter of personal preference.

Second, two-factor theories must postulate a complicated chain of events which cannot be observed and, hence, must be assumed to be occurring within the organism. Response-produced stimuli are assumed to elicit conditioned fear which can be escaped from or avoided by emitting a non-response (equally unobservable). Further, the responses presumed responsible for producing the stimuli which are assumed to elicit conditioned fear are not themselves systematically observable, and, hence, must be presumed to be occurring internally as well -- a very dubious chain of assumptions and presumptions.

Crucial to Mowrer's two-factor explanation of punishment is the development of non-responding being maintained by negative reinforcement -- i.e., escape from conditioned fear. Rachlin and Herrnstein (1960) reasoned that if non-responding was the selected response to be punished and reinforced, then, given a two-factor explanation of response decrement due to punishment, an increase in non-responding and a decrease in responding should be observed. They trained four pigeons to peck a key whose color alternated every two minutes between red and green. When the stimulus key was red, a response would occasionally produce either positive reinforcement or shock. If, however, a non-response (defined as a five second periond in which no response occurs) followed the "priming" (Rachlin and Herrnstein's term for the setting up of either punishment or reinforcement) of either a reinforcement or a punishment, then neither the reinforcement nor punishment was not delivered. Under the green stimulus contingency the situation was reversed; a non-response would occasionally produce either reinforcement or shock. If either a reinforcement or punishment was primed to occur and the subject responded prior to making a non-response, then the reinforcement or shock was not delivered. Under these conditions responding during red showed increased suppression as a function of increasing shock intensity (from 0-15 ma), but no similar suppression of non-responding occurred during green. Rachlin and Herrnstein concluded from this data that if a two-factor theory is correct, then the amount of suppression of non-responding during green should have been symmetrical with the amount of suppression of responding during red. This was not, however, the case.

Given these kinds of considerations, Rachlin and Herrnstein recommend a return to a formulation of the law of effect similar to Thorndike's initial one.

Azrin and Holz (1966) have proposed a definition of punishment similar to Thorndike's (1913) negative law of effect, which avoids the above objections and is a formulation of a negative law of effect. They define punishment as "a reduction of the future probability of a specific response as a result of the immediate delivery of a stimulus for the response." The contingent stimulus which results in a decreased probability of responding is designated as the "punishing stimulus". First, it should be possible to precisely specify the physical parameters of the stimulus in terms of its intensity and duration. Second, the stimulus should be constant in terms of its contact with the organism. That is, although the physical dimensions of the stimulus may be precisely specified, its effect on the organism may vary depending on the animal's physical orientation. impedence (in the case of electric shock), etc. Third, it should not be possible for the organism to respond in a way such as to minimize or avoid the effects of the punishing stimulus. Fourth, there should be few and mild skeletal reactions to the stimulus. Intense or long lasting skeletal reactions might themselves be responsible for the decrement in responding, rather than the punishing stimulus. Fifth, the stimulus should be variable over a wide range of values, providing response reduction from negligible to complete.

Several types of punishing stimuli have been used: air blasts (Masserman, 1946), bar slap (Skinner, 1938), noise (Azrin, 1958), tail pinch (Azrin, 1965), time out (Azrin, 1966), and electric shock (Azrin, 1958).

Electric shock has been the most extensively used punishing stimulus. It meets several of the requirements for an ideal punishing stimulus. It can be specified fairly precisely in terms of its physical characteristics. It can be varied over a wide range of values with concomitant changes in response rates. At less than tentanizing levels of intensity and with short durations it evokes few or no skeletal reactions outlasting the duration of the electric shock itself. Electric shock fails to be an ideal punishing stimulus on two counts. First, it is difficult to insure that constant contact with the organism is maintained. Changes in the impedence and orientation of the organism effect the shock intensity "experienced" by the organism. Second, with some techniques of shock delivery it is possible for the organism to orient itself in a way which either minimizes or completely avoids contact with the shock.

Typically in animal research, shock is delivered either to the soles of the organism's feet (Church, 1969), through skin electrodes attached to the organism (Azrin, 1959), or through chronically implanted electrodes (Azrin, 1959). The use of either skin or chronically implanted electrodes reduces the possibility of the organism either minimizing or avoiding the shock by orienting. However, the use of either skin or chronically implanted electrodes presents some problems in a free operant paradigm in that their use usually requires some restriction of the organism's movement. Consequently, shock delivered to the feet through a grid floor is typically used. Dinsmoor (1961) has developed a shock source which minimizes current fluctuation due to changes in the organism's impedence. Skinner and Campbell (1947) developed a system for changing the polarity of the shock delivered to the grids to avoid the possibility of the organism avoiding the electric shock by standing on grids of like polarity. Dinsmoor (1958) used large tubular grids to minimize shorting between the grids and to maximize the organism's contact with the grids.

Morse and Kelleher (1968, 1970) further emphasize the necessity of defining a stimulus in terms of its effect on behavior. They point out that the same stimulus for a given organism can function either as a punisher or a reinforcer, depending on the conditions under which the stimulus is presented. The effects of a given stimulus on responding will depend, in part, on the organism's previous experience with the stimulus, the schedule on which the stimulus is presented, and the behavior of the organism.

APPENDIX II

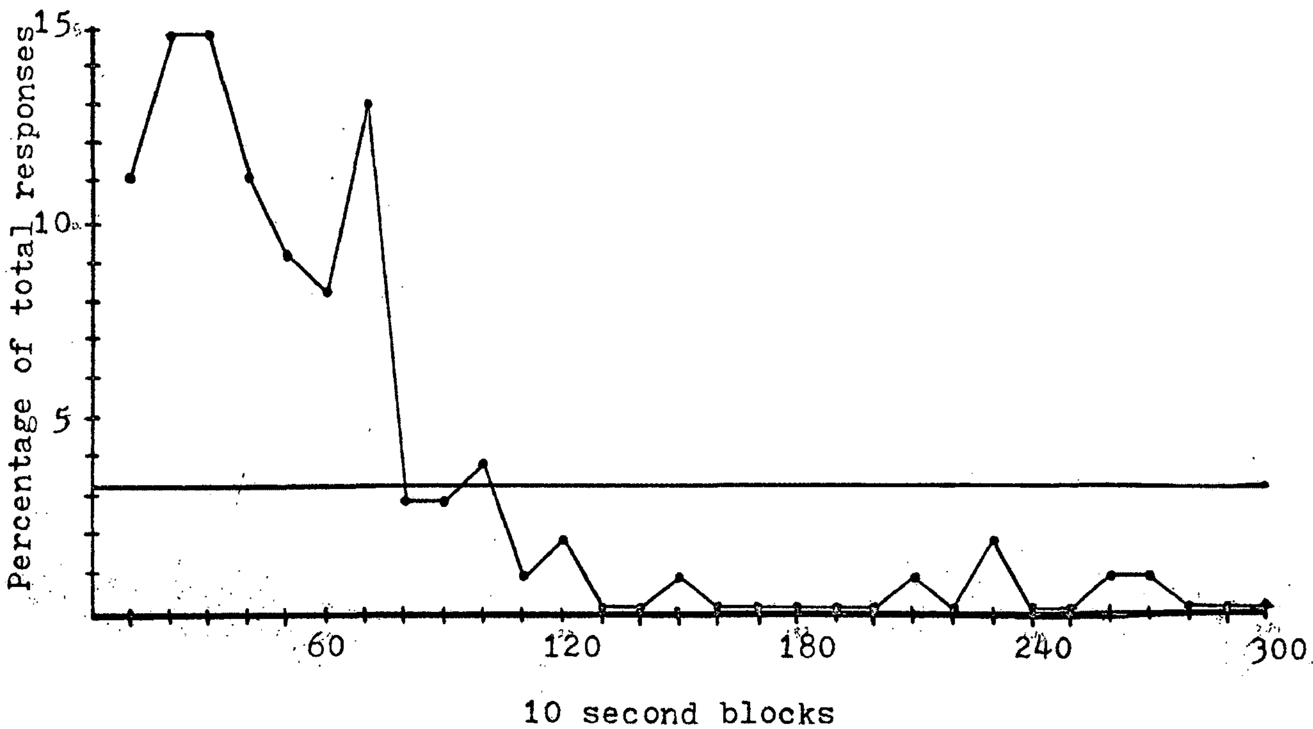

Fig. a Percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day 60 of the shock condition for subject 9. The heavy line at 3.3% is the expected percentage of responses given no effect from the shock.

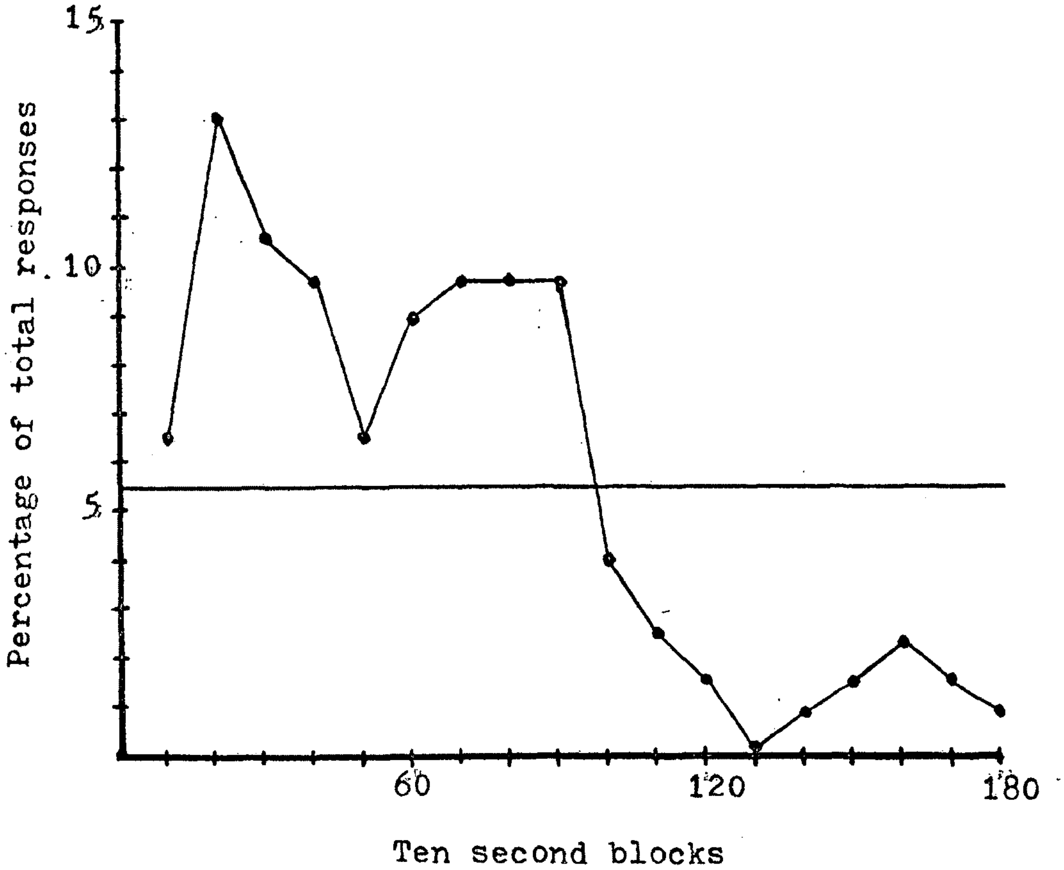

Fig. b Shows the percentage of responses made in each post-shock 10 second block across the inter-shock interval, for day 30 of the shock condition for subject 5. The heavy line at 5.5% is the expected percentage of responses given no effect from the shock.