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PUNISHMENT OF FIXED RATIO RESPONDING MAINTAINED BY A CONCURRENT SCHEDULE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Punishment of Fixed Ratio Responding Maintained by a Concurrent Schedule" submitted by Sally A. Goforth in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

Four squirrel monkeys (Saimiri sciureus) were trained to respond under a fixed-ratio schedule of reinforcement in which the reinforcer consisted of a one minute time out from a free-operant avoidance schedule. Following stabilization of performances engendered by the concurrent schedule, fixed-ratio responses were punished selectively by means of response-contingent electric shocks presented following the first, middle, or last effective response of the ratio. The three punishment conditions exerted differential effects upon behavior. Punishment of the first response consistently produced longer post-time out pauses, with an increased rate following the delivery of response-contingent shock, as compared with control performance. Punishment of the middle response led to disruptions of responding and a lowered rate during the first half of the ratio, and a heightened, shock-initiated rate during the last half of the ratio. Disruptions and low-rate responding occurred throughout the ratio for punishment of the last response. These effects are consistent with the effects of punishing fixed-ratio performances maintained by other positive reinforcers, such as food. Other differences were found. Recovery under punishment was not obtained, most notably at higher intensities of punishment, and suppression of responding, attributable to punishment, occurred gradually rather than immediately. It is suggested that these findings are related to the presence of an alternate response within the concurrent schedule and to shock-discrimination factors.

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Sally A. Goforth

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PUNISHMENT OF FIXED-RATIO RESPONDING MAINTAINED BY A CONCURRENT SCHEDULE

Introduction

It has been demonstrated that a period of time out from a Sidman avoidance schedule (Sidman, 1953) can function as a reinforcer although its effectiveness as a reinforcer has not been settled in the literature. One method of investigating its reinforcing value is to punish the behavior producing the time out.

The effects of punishment on behavior have been extensively investigated, with several properties of punishment emerging consistently. If the effects of punishing behavior maintained by time out from an avoidance schedule are similar to effects of punishing behavior maintained by more conventional reinforcers a qualitative similarity between the two kinds of reinforcers would be suggested.

The research described in this thesis was planned to investigate the effects of punishment on ratio performance maintained by time out from a Sidman avoidance schedule. The concurrent schedule used is a complex one, with both escape and avoidance factors involved. After a brief discussion of some of the basic concepts, relevant research areas will be reviewed. These include studies showing the effects of time out from reinforcement, the effects of termination of aversive stimulation, typical patterns of FR performance, and the changes which emerge when ratio behavior maintained by more conventional reinforcers is punished. The concurrent schedule used in this research will be explained in greater detail later in the introduction after some of the components of the schedule have been examined.

BASIC CONCEPTS

As Verhave (1962) and others have noted there are four general ways to arrange reinforcement in order to modify behavior. A response can be followed by the presentation of a positive reinforcer, the presentation of a negative reinforcer, the removal of a positive reinforcer, or the removal of a negative reinforcer.

Morse (1966) has given the following definition of a reinforcer. "A reinforcer (reinforcing stimulus) is an event which changes subsequent behavior when it follows behavior in time." A positive reinforcer is a stimulus, such as food, which increases the probability of a response which produces it. This definition is not entirely circular, since a reinforcer can be identified in one situation and then used in other situations to control behavior. Other factors, such as satiation, can render a reinforcer ineffective. For this reason it is not possible with certainty to identify a reinforcer under new conditions, although the term remains useful. A stimulus may be defined as a negative reinforcer when the probability of a response which terminates, reduces, or postpones the stimulus is thereby increased. Definitions of both positive and negative reinforcers vary throughout the literature and the ones chosen here ignore the finer points of disagreement. Ambiguity in identifying an aversive stimulus has proven an even greater problem than in the identification of a positive reinforcer. In general, however, the distinction between the two has remained sufficiently clear to justify the four methods earlier mentioned for arranging reinforcement contingencies.

PRESENTATION OF POSITIVE AND NEGATIVE REINFORCERS

The presentation of a positive reinforcer is the procedure most frequently referred to when the term reinforcement is used. Most investigations of the effects of schedules of reinforcement have used this method. A schedule of reinforcement is a program arranging contingencies between responses and reinforcers. This relationship may be based on the number of responses or the time since the last reinforcement. In addition, the relationship can be fixed or it can vary according to some plan. This gives rise to the four basic schedules of reinforcement: fixed ratio (FR), variable ratio (VR), fixed interval (FI), and variable interval (VI) schedules. More complete definitions of these schedules as well as many possible variations and combinations of schedules are given by Ferster and Skinner (1957). Various schedules can also be used to determine the effects of presentation of negative reinforcers, although the work in this area has not been as comprehensive.

Presentation of a negative reinforcer following a response is a punishment procedure. As in the case of positive reinforcers punishment may be presented on ratio or interval schedules. The usual, although not invariant (Morse, Mead, and Kelleher, 1967; McKearney, 1968; Stretch Orloff and Dalrymple, 1968) consequence is suppression of responding. Degree and pattern of suppression depend on such factors as intensity of the aversive stimulus (Appel, 1963), the schedule of positive reinforcement originally maintaining the behavior (Azrin, 1958; Azrin, 1959), the schedule of negative reinforcement (DeArmond, 1966), the immediacy of punishment (Azrin, 1956), and prior exposure to the aversive stimulus (Azrin, Holz, Hake, 1963).

Several characteristics of punishment have appeared throughout punishment studies. Under intense punishment suppression may be so complete that recovery does not occur for long periods after punishment has been removed. Holz and Azrin (1966) suggest this may be due to suppression of responding below the operant level so that there is no opportunity for the subject to detect the absence of punishment. Recovery and compensatory effects have also been found. Azrin (1960) showed clearly that continued exposure to punishment led to recovery, both within each session and from day to day as sessions continued. Upon removal of punishment a compensatory increase in responding above the pre-punishment baseline appeared briefly. Other facilitative effects of punishment on an alternate unpunished response have been observed by Brethower and Reynolds (1962). When rate of punished responding declined during the presence of one stimulus, rate of unpunished responding increased in the presence of another stimulus. Upon removal of punishment the increase in previously punished responding was accompanied by a corresponding decrease in rate of the always unpunished responding.

Other properties of punishment are related to its discriminative rather than its aversive function. Holz and Azrin (1961) found that when a severe punishment was differentially paired with reinforcement, punishment served to increase responding. After positive reinforcement was removed, response rate was higher with punishment than when both punishment and reinforcement were absent. In addition, when paired with extinction, a generally ineffective punishment could decrease responding. In a later study (Holz and Azrin, 1962) interactions between the discriminative and aversive properties of punishment were investigated. A fixed interval schedule of food reinforcement was viewed as a period of extinction followed by an opportunity for reinforcement, and punishment was selectively paired with different portions of the interval. At milder shock intensities discriminative control was similar to that of a neutral stimulus. At higher intensities, when associated with extinction (during earlier unreinforced segments of the interval) the aversive property acted with the discriminative property to further reduce responding. When associated with reinforcement, the aversive and discriminative properties worked against each other so that response rate was lower than when a neutral discriminative stimulus was used but higher than when no discriminative stimulus was present.

These discriminative properties of punishment have been used by Azrin and Holz (1966) to account for some of the findings previously presented as paradoxical in the punishment literature.

REMOVAL OF POSITIVE AND NEGATIVE REINFORCERS

Both escape and avoidance contingencies are procedures involving the removal of an aversive stimulus. In escape, a response terminates the aversive stimulus after it has begun; in avoidance the animal may prevent or postpone the occurrence of the noxious stimulus by a response. An overlap exists between the two contingencies. In escape procedures, by terminating the noxious stimulus, its continuation is avoided. In avoidance procedures, an escape from conditioned aversive stimulation occurs. The latter is most clear in avoidance schedules in which the subject terminates a warning signal, the conditioned aversive stimulus, and avoids a shock. In avoidance contingencies without a signal the passing of time has been suggested as the discriminative stimulus (Reynolds, 1968). Reynolds stated that "a long time since the last response" becomes the conditioned aversive stimulus. Anger, 1963, suggested that stimuli occurring shortly after a response would have a relatively low aversiveness due to their remote relation with shock. Aversiveness should increase as the time since the last response approached the response-shock interval. Since the avoidance response changes a long post-response time to a short post-response time, the consequent decrease in aversiveness reinforces the response. However, a later paper by Herrnstein and Hineline (1966) showed that rats on a modified avoidance schedule would respond to reduce the overall rate of shock when no covert stimuli of a temporal nature could be inferred. Reduction in shock frequency alone was sufficient to maintain the avoidance behavior. The source of the reinforcement for unsignalled avoidance schedules thus seems open to doubt. The only clear distinction between avoidance and escape procedures seems to be that under avoidance contingencies it is possible for the animal to completely avoid the primary aversive event while under escape contingencies it is only possible to partially avoid the aversive stimulation. Conditioned aversive stimuli may be present in both cases.

Another group of studies involving removal of reinforcers are those using time out (TO) periods. These may either be periods in which the opportunity for positive reinforcement is no longer available (TO from positive reinforcement) or periods in which there is no possibility of the occurrence of the aversive stimulus (TO from aversive stimulation). Because of their relevance for the present research, findings from these TO studies will be examined in greater detail.

<u>Aversive properties of time out from positive reinforcement</u>: The earliest studies of the effects of time out dealt with the aversive properties of a time out period in which positive reinforcement was no longer available. Ferster (1958) used a stimulus in the presence of which reinforcement could not be obtained and called this the time out (TO) stimulus. He showed that this had many of the properties of commonly recognized aversive events such as shock. However, in a review of the literature Leitenberg (1965) indicated that this conclusion is open to doubt. He suggested that in the studies investigating avoidance of TO from positive reinforcement another interpretation, other than the aversiveness of TO, was possible. The studies could merely indicate that subjects will maintain behavior which leads to positive reinforcement; the patterns of behavior followed by most frequent reinforcement are most strengthened. Since a TO prevents the occurrence of a reinforcement it is natural that the animal will learn other more advantageous patterns of behavior with the consequence that TOs are avoided. This could also explain the results of some TO-punishment studies, in which the TO is response-contingent, since a higher frequency of reinforcement is maintained following response suppression.

In some of the TO studies an alternative response is available, while in others the animal must continue to respond, under punishment by TO, if even a minimum of reinforcement is to be obtained.

Holz, Azrin, and Ayllon (1963) used TO from positive reinforcement with mental patients and found behavior was not suppressed if there was no alternative means of obtaining reinforcement. When an alternative response was introduced, however, the punishment was effective. All of the matching-to-sample studies (for example, Ferster and Appel, 1961; Zimmerman and Ferster, 1963) have punished only incorrect responses. Since an alternate correct response was available these studies generally indicated TO was effective in suppressing the incorrect response. On the other hand, investigations of the effects of a signal preceding an unavoidable TO (Ferster, 1958) indicated that responding was increased rather than suppressed in the presence of the stimulus. This is in contrast to the suppressive effects of a pre-shock stimulus, if the shock is unavoidable. These findings seem to fit in well with Leitenberg's suggestion that maximizing reinforcement may be the crucial factor in studies of TO from reinforcement. If the animal is unable to improve his chance of being reinforced, behavior is not suppressed following TO-punishment. One somewhat contradictory experiment is that of Ferster (1960) who found that monkeys gave no evidence that time out became less aversive as the schedule of reinforcement became less favorable. Even in this experiment, however, reinforcement continued to occur relatively more frequently if responding ceased during the pre-TO stimulus for the unfavorable as well as the favorable schedules of reinforcement. Two other experiments (Adelman and Maatsch, 1960; Wagner, 1963) showed that rats would learn to escape from stimuli associated with TO, and largely on this basis Leitenberg concluded that TO can be considered an aversive event, although the conclusion was tentative.

A later study by McMillan (1967) directly compared the punishing effects of shock with the punishing effects of TO in the squirrel monkey (<u>Saimiri sciureus</u>). He found that shock-punishment (1-3 ma, 30 msec.) and TO-punishment (60 sec. to 90 sec.) suppressed responding on a VI baseline to about the same degree. Although McMillan was impressed by the similarities between the effects of the two procedures, two differences were revealed. Shock-punished responses tended to recover within a session, while TO-punished responses did not. In addition, long pauses tended to occur between the termination of the shock-punishment component and resumption of VI responding, while responding resumed almost immediately following termination of the TO-punished component. Since responding during the TO-punished component lengthened the period of time during which reinforcement was unavailable, these findings might also be subsumed under the principle of maximizing reinforcement. McMillan suggested that the suppression produced by TO occurred partly because stimulus changes associated with TO were aversive and partly because of the differential reinforcement under the low response rate.

Reinforcing properties of time out from aversive stimulation: Several studies have shown that animals will learn to escape from conditioned aversive stimulation into a TO period under a variety of schedules (discussed by Morse and Kelleher, 1966). This discussion is restricted largely to those utilizing fixed ratio (FR) schedules because of their particular relevance.

Azrin, Holz, and Hake (1962) delivered brief electric shocks to squirrel monkeys in the presence of a light. They found that responding could be sustained on a ratio schedule of 25 to 350 responses when reinforcement was removal of the light, with consequent shock termination. Since shocks occurred during responding and the animals maintained responding in spite of this virtual punishment of individual responses, the authors concluded removal of the conditioned aversive stimulus was the important source of reinforcement.

A more recent study involving FR termination of aversive stimulation is that of Azrin, Hake, Holz, and Hutchinson (1965). Pigeons were allowed to escape from a situation in which food reinforced responses were punished into a situation in which the responses were not punished. Responding was maintained under FR requirements up to 200. The frequency of escape responses was a direct function of shock intensity. This relationship held true regardless of resulting decreases or increases in frequency of food reinforcement and whether a stimulus change occurred at the onset of the safe period or was omitted. Stimulus change alone had no effect on escape responding unless accompanied by elimination of the punishment contingency. This indicates that removal of the conditioned aversive stimulation may not have been as important a factor as removal of the aversive stimulation per se in the Azrin, Holz, and Hake (1962) experiment mentioned earlier.

The studies just discussed dealt with termination of aversive stimulation. Recent studies have indicated that avoidance schedules, in which the subject responds in order to avoid shock, are themselves aversive. Findley, Schuster, and Zimmerman (1966), working with Mangabey monkeys (Cercocebus), found that a stimulus associated with avoidance could maintain a secondary escape response which delayed occurrence of a period of shock-avoidance. If the animals failed to respond in the presence of a blue light either a food reinforcement or shock avoidance trial followed. A response in the presence of the blue light led to S^{Δ} and avoided the food or avoidance stimulus. Under low probability of a food trial or during satiation the monkeys learned to respond in order to avoid stimulation associated with shock avoidance periods.

This ability of animals to learn a second-order escape response is consistent with other experiments showing animals will learn to escape from avoidance contingencies into a time out period.

Verhave (1962) demonstrated that rats will learn to press a lever to produce a cue associated with a TO from a Sidman avoidance schedule (TOav). The first experiment failed to provide evidence that TOav exerted a reinforcing effect. An avoidance schedule was operative in the presence of one set of stimuli while in the presence of other stimuli (TOav) no shocks occurred. When the program was arranged so that the first bar press after 15 minutes of the Sidman avoidance contingency produced a 15 minute time out period, no scalloping appeared. (Since the removal of an aversive stimulus is generally reinforcing the positively accelerated rate changes characteristic of FI reinforcement had been expected.) At this time a second lever was made available by which a TO could be obtained. Using this method, responding on the TO lever was maintained for small FR values. Fixed-ratio performance showed curvature with responses occurring in bursts that increased in length toward the end of the FR run. Verhave concluded that stimuli associated with a time out from an avoidance schedule can function as a positive reinforcer but a relatively weak one. This was based on his finding that behavior could be maintained only at low valued ratios and FR strain was marked considering the low values. He suggested, however, that the demonstration of the reinforcing function of TOav had significance for interpretation of avoidance conditioning. In both cases, the reinforcing event is the absence of a stimulus (shock), which is sometimes considered problematic. Verhave noted that the absence of shock is, in itself, a stimulus condition associated with the non-occurrence of shock (TOav). The intertrial intervals during avoidance conditioning might be considered as TOav periods.

In another TOav experiment Sidman (1962) used rhesus monkeys (Macaca mulatta) rather than rats. The animals could avoid shock by pressing a lever and could produce a five minute time out period by pulling a chain on a FR schedule. To prevent adventitious reinforcement of the lever pressing by the time out, a two second delay requirement was added to the fixed ratio. The time out period could be produced only after the delay period had elapsed. Prior to the experiment the monkeys had worked on a concurrent schedule in which shock was avoided by pressing the lever while food reinforcement was obtainable by a fixed number of pulls on the chain. Considerable transfer of this behavior occurred when a time out replaced the food reinforcement. Fixed ratio values of 75 and 100 responses were maintained with little evidence of strain. An analysis of switching behavior between the lever and the chain revealed that the length of the run of chain pulling increased as the FR requirement approached completion. This is consistent with the observations of Verhave. Complementing this pattern, the number of lever presses before switching back to the chain decreased as the animal progressed in the ratio. The evidence that this study provides for the effectiveness of TOav as a reinforcer capable of establishing FR behavior is confused somewhat by the transfer of earlier FR performance on the same manipulandum. Time out from avoidance did function to effectively maintain FR behavior at moderately high values, however.

Findley and Ames (1965) worked with a chimpanzee to determine the effects of reinforcing responding by TOav on a fixed interval schedule. The shock avoidance schedule was programmed concurrently with a 4 hour FI schedule reinforced by an 8 hour time out period. The two contingencies were programmed on separate switches. At the beginning of an avoidance period a light came on; a response could terminate the light and avoid an impending shock. Two avoidance schedules were alternated after each 8 hour TO. On one the response-light interval was 15 minutes and for the other it was 15 seconds. Initially high FI response rates were obtained with the short response-light interval and lower FI rates were associated with the longer avoidance interval. However, these differences in TO rate tended to diminish as training continued. The authors suggested that the decline in TO responding was due to the partial discrimination of the FI contingency, permitting the onset of TO to be relatively independent of response rate. It seems possible that the greater work requirement to avoid shock along with the greater shock frequency under the short response-light intervals motivated the animal more strongly to escape into a time out period. As the animal gradually discriminated the independence of response rate and escape into a TO, the rate reduction occurred.

Findley and Ames' results indicate that the aversiveness of an avoidance schedule depends on the parameters used. Both the animal's efficiency in avoiding shock and the work requirement necessary to avoid the shocks may be important factors in determining the reinforcing properties of TOav. The counterpart to Leitenberg's suggestion that maximizing reinforcement is the major factor behind the aversiveness of TO from positive reinforcement can be examined for TO from avoidance. In this case the reinforcing properties of the TO may not be as basic as the minimization of shock and minimization of the work requirement.

An evaluation of the reinforcing properties of TOav would necessitate an examination of the effectiveness of the TO as a function of: (a) number of shocks actually delivered during the avoidance period and (b) the relationship between the output necessary to produce the TO compared with the output necessary to effectively avoid shock. If it could be demonstrated that animals will work to produce a TO even if the work output is as great, or greater, than that required to efficiently avoid shock and even when the number of delivered shocks is not reduced, it would more clearly be demonstrated that the TO itself has reinforcing value. An investigation of the secondary reinforcing properties of stimuli associated with TOav might also be helpful in evaluating the strength of the reinforcement involved. Another approach would be that of investigating the resistance of the TO responding to suppression under punishment and to compare the effects of punishing TOav-reinforced responding with the effects of punishing food-reinforced responding. The last mentioned approach is the one taken in the present experiment.

This research is concerned with the effects of punishment on a concurrent time out from avoidance schedule when the time out is produced by a FR requirement. A Sidman schedule (Sidman, 1953) is programmed on one manipulandum while a FR contingency on another manipulandum allows escape (or time out) from the Sidman schedule for a specified length of time. On a Sidman schedule every press of the manipulandum resets a timer controlling shock, thus delaying its occurrence for a specified length of time. No warning signal prior to a scheduled shock is given. The length of time between a response and the next scheduled shock (the R-S interval) as well as the period of time between shocks if no response occurs (the S-S interval) may vary. Prior studies have investigated the effects of punishment of FR behavior when the responding is maintained by food reinforcement, but not when the reinforcing event is a period of time out from aversive stimulation.

Ferster and Skinner (1957) define a concurrent schedule as "two or more schedules independently arranged but operating at the same time, reinforcements being set up by both." Catania, Deegan and Cook (1966) have added further precision to this definition by confining the term concurrent schedule to situations in which there is a separate manipulandum for each of the two components of the schedule. They prefer the term conjoint schedule when both components are programmed on the same manipulandum. Conjoint and concurrent fixed ratio and Sidman avoidance schedules similar to the present one were used by Kelleher and Cook (1959) and Catania, Deegan and Cook (1966) respectively. In these studies, however, food rather than TOav reinforced the FR behavior. Kelleher and Cook used a one lever rather than a two lever arrangement, which makes difficult a separation of the FR performance and the avoidance performance in order to compare them with similar TOav studies. However, an examination of the cumulative records indicated abrupt shifts from avoidance-controlled to FR-controlled behavior which allows some separation of the two response patterns. In addition, another study (Catania, Deegan and Cook, 1966), using the same kind of concurrent schedule, showed rate of responding maintained by either contingency was not affected by removal of the other contingency. This means that Kelleher and Cook's results obtained upon extinction of avoidance responding should be representative of the FR patterns under the concurrent schedule. Keeping in mind these assumptions, a comparison of Kelleher and Cook's study using food reinforcement with Verhave's study of a similar concurrent schedule using TOav reinforcement may be made. Both studies used rats. The response-shock (R-S) and shock-shock (S-S) intervals were different for the two Sidman schedules but since these intervals were shorter in Verhave's TOav study this should have favored a higher rate of FR responding (as indicated by Findley and Ames, 1965). Much higher and more stable rates were obtained under food reinforcement, however, This superiority of food reinforcement to TOav reinforcement with rats is further supported by Verhave's report that some rats would stop working on the TO lever at ratio values as low as 10 and would switch to the avoidance lever alone.

Since Catania, Deegan and Cook (1966) used two levers for their study of concurrent avoidance and FR food-reinforced schedules, a more direct comparison of this study with similar studies using TOav reinforcement is possible. Although Catania et al. used squirrel monkeys and Sidman (1962) used rhesus monkeys, both maintained them under FR 100 requirements, and used a two-manipulanda arrangement. The major differences were that Sidman used a chain rather than a lever for one manipulandum and used RS=SS=20 rather than RS=SS=30 as the avoidance parameters. Performances were markedly similar under the two different types of reinforcement. The performance of the monkeys reinforced by TOav was comparable to the performance of the food-reinforced monkeys designated as high-rate responders. Some of the other monkeys in the study using food reinforcement responded at much lower rates than any of the monkeys in the study reinforced with TOav.

These comparisons point to contradictory conclusions, since studies with rats suggested more difficulty maintaining FR behavior when reinforced with TOav than when reinforced with food; monkeys, on the other hand, maintained stable high rates using either type of reinforcement. This suggests that Verhave's conclusion that TOav can function only as a weak positive reinforcer should be left open to doubt at least so far as work with monkeys is concerned.

In spite of the unsettled question as to the effectiveness of reinforcement by TOav, studies seem to agree that FR behavior established under TOav has characteristics similar to FR behavior established under food reinforcement. Thus an examination of characteristics of FR behavior and of the effects of punishing FR behavior maintained by more conventional reinforcers should have relevance for the punishment of FR behavior maintained by TOav.

FIXED RATIO PERFORMANCE

In a fixed ratio schedule, a specified number of responses produces a reinforcement. Since frequency of reinforcement increases with higher rates of responding, rates tend to be high. When pauses or slow rates occur this, typically, is immediately following reinforcement when the probability of another reinforcement is lowest. Once the animal begins to respond, however, he usually maintains the high terminal rate until the required number of responses has been completed. As the number of responses required in the fixed ratio increases the pause increases in length, although some evidence suggests the running rate increases. Boren (1953) found that rate of responding increased with ratio size up to FR 25. Ferster and Skinner (1957) also agree that rate is higher for moderate size ratios than for small ratio requirements. Since decrements in frequency of reinforcement could be expected to occur with large ratio values, Morse (1966) suggests that any increase in rate may be related to the typical increase in rate following decrements in reinforcement frequency. A general and consistent finding with ratio schedules seems to be that an increased rate follows periods of deceleration which have been accompanied by lessened reinforcement. This compensatory effect has also been observed in the reverse direction with increases in rate and number of reinforcements being followed by deceleration so that a kind of balance seemed to be achieved.

Accordingly, when time outs are introduced into ratio schedules, the TO should reduce the frequency of reinforcement and lead to increased rate following the time out. In addition, since the stimulus control from the preceeding ratio performance is reduced, the post reinforcement pause should be altered. Ferster and Skinner (1957, p. 116-119) show records which indicate the pause is frequently reduced or eliminated following time outs. If the time out continues to consistently follow reinforcement it may itself exert discriminative control and lead to increased pausing. Ferster and Skinner found this to be particularly true under large ratio requirements. Evidence presented earlier which indicated that TO from positive reinforcement can function as punishment and lead to decreases in rate of responding is not necessarily inconsistent with these findings. In the design of Ferster and Skinner, no alternative method of reinforcement was available, so that any decrease in rate following a TO automatically led to a decrease in reinforcement frequency over time. Important factors in the effects of TO from positive reinforcement on ratio schedules seem to be the presence or absence of an alternative response for producing reinforcement, the size of the ratio requirement, and the amount of exposure to the TO conditions. If exposure continues, the control formerly exerted by the prior performance and reinforcement is eventually exerted by the TO. The TO becomes the cue that reinforcement is not available until the response requirement is again met and can control a low or zero rate of responding immediately following its termination.

<u>FR punishment</u>: Punishment of FR performance produces characteristic changes in pattern of responding. Azrin (1959) punished pigeons for every response on an FR food-reinforced schedule. Upon the initial introduction of punishment the characteristic pattern of FR behavior,

pausing followed by high rates, was disrupted. After a few sessions, however, reduction in rate was due mainly to lengthening of post reinforcement pauses with little change in terminal rate. These pauses decreased throughout the session, with recovery of prepunishment rate for low and moderate punishment intensities. Under higher intensities pauses were longer and little recovery occurred. Once responding was initiated, however, a high terminal rate was maintained.

Since Azrin applied punishment to all responses it is not possible to determine from these results whether punishment of some portions of the ratio is more effective than punishment of others. Dardano and Sauerbrunn (1964a) investigated the effects of increasing and decreasing shock intensity for successive thirds of the ratio. Under these conditions the punishment would be expected to acquire discriminative properties in addition to the noxious ones. Under the increasing intensity, pausing increased as the ratio advanced, and local rate in the last part of the ratio was lowered. Despite the decreased rate, responding was resistant to breaks during the last third of the ratio for all intensities. Greater suppression, manifested mainly by response breaks and marked increases in pausing at the beginning of the ratio, occurred under decreasing intensity. The authors suggested the decreasing intensity condition was more effective because maximum punishment was applied to the part of the ratio in which probability of response was lowest.

In a later study (Dardano and Sauerbrunn, 1964b) the effects of punishing different parts of the ratio were further investigated. Pigeons on an FR 50 food-reinforced schedule were punished by shock for the first, middle, or last response of the ratio. Intense punishment of the first response led to prolonged pauses after reinforcement, breaks and rough grain at the beginning of the ratio. As found previously, terminal rate was at the pre-shock level. At lower intensities an increased pause was the only consistent finding. When the middle response was punished the entire first half of the ratio was disrupted and pauses after reinforcement were more variable, though rate was still maintained in the last half. Even greater irregularities occurred under punishment of the last response; with intense shock, response breaks and rate changes appeared throughout the record. After removal of punishment recovery was abrupt rather than gradual for all conditions. In trying to understand the dual aversive and discriminative properties of the shock the authors suggested viewing the ratio as a chained FR-shock FR-food sequence. Punishment of the middle response disrupted performance during the first half of the ratio and then became the signal for non-punished responding on the food reinforced portion of the chain. Similarly, shock had its major effect on the pause after reinforcement for FR-1 punishment (punishment of the first response of the ratio) and was the signal for shock-free responding throughout the rest of the ratio.

Dardano and Sauerbrunn's findings for FR-1 punishment are similar to Azrin's results for continuous punishment since the main effect in both cases was increased pausing at the beginning of the ratio. A comparison of these two effects was made by DeArmond (1966). A multiple punishment schedule was used which provided continuous punishment under one discriminative stimulus and punishment of the first response under the other stimulus condition. The two stimuli were alternated on the response key. Little change in rate occurred when moderate intensity shock was introduced after every response or when it was introduced after the first response alone. When punishment of the first response in one component of the schedule was changed to continuous punishment, however, rate was reduced. This occurred even though suppression did not take place if the initial exposure was to continuous punishment. When continuous punishment was followed by first response punishment, little suppression occurred. For continuous punishment, increased post reinforcement pausing occurred early in the session with recovery taking place by the end of the session. Both warm-up and session-to-session recovery were noted.

In contrast to Dardano and Sauerbrunn's findings, little change in total rate was found for FR-1 punishment. The differences in intensity between the two studies might explain this inconsistency.

Azrin, Holz, and Hake (1963) also found continuous punishment to be more effective than intermittent, with the amount of suppression being a direct function of the proportion of responses punished. In this study FR punishment was superimposed on a VI schedule of food reinforcement. Initially responding was positively accelerated between punishment; that is, responding was suppressed immediately following punishment and gradually increased until the next punishment. Gradually this pattern of suppression changed until a reduced but uniform response rate emerged. The size of the punishment ratio determined the extent of reduction but did not affect the uniform rate of responding. Characteristic warm-up periods (initial suppression with subsequent recovery) appeared at the beginning of sessions for lower intensities, although this recovery within sessions did not occur for higher intensities. The authors noted that this warm-up phenomenon was probably not due to sensory adaptation since, under intermittent punishment, shocks were separated in time. A decreasing rate between punishment was rarely observed and was not sustained by any of the experimental animals. The expectation that punishment, since it is the occasion upon which succeeding responses are not shocked, would become a discriminative stimulus and initiate heightened rates was not confirmed. Upon termination of FR punishment, response rate exceeded the pre-shock level for the first few hours.

Hendry and Van-Toller (1964) imposed FR punishment on a schedule of continuous food reinforcement and were able to obtain the positive acceleration expected but not observed in the previous study. The authors suggested that since the VI food reinforcement schedule used by Azrin et al. would differentially reinforce a low rate, any tendency of the punishment to produce high rates could have been counteracted. Continuous reinforcement does not differentially reinforce a low rate, and under this condition differentiated response rate between punishment emerged.

A study by Storms and Boroczi (1966) adds a qualification to the relatively consistent finding that continuous punishment suppresses behavior more effectively than intermittent punishment. In their study continuous punishment was more effective than partial punishment only for short shock durations. As the duration increased no differences in the suppressive effects of punishment of every response, every second, fourth, or eighth response were observed.

The investigations cited above indicate that punishment of FR behavior shows many of the phenomena associated with punishment in general. Intersession and intrasession recovery, compensatory increases following removal of punishment, and discriminative and aversive functions were apparent. Different patterns of suppression were observed depending on the portion of the ratio punished. In general, FR punishment was less effective in reducing response rate than continuous punishment for a variety of positive reinforcement schedules. Whether FR punishment led to differentiated responding or to a uniformly suppressed rate was dependent on the type of baseline schedule. When a VI schedule was used rate was uniformly reduced, but for a continuous schedule of reinforcement a decelerating rate between punishments gradually emerged. In both cases the initial, though temporary, effect of introduction of punishment was an accelerating rate between punishment. As discrimination developed this pattern changed.

Since this thesis involves punishment of the first, middle, or last response of ratio performance, behavioral properties observed for punishment of FR behavior might be expected to appear. The positive reinforcer maintaining the baseline behavior is TO from avoidance. In this TOav schedule an alternative mode of response is built into the schedule since the animal avoids the shock either by pressing the avoidance lever or by producing the TO. Research on TO from positive reinforcement indicated that the effectiveness of the TO in shaping behavior depended on whether an alternative response for obtaining reinforcement was available. If an alternate method could be used which did not produce a TO, the TO-punished response was suppressed; otherwise suppressive effects were slight. The situation is changed when a TO from aversive stimulation is involved. The presence of an alternate response should still be important but now it is the effectiveness of the TO as a positive reinforcer which must be considered. Obviously the animal has the choice of switching to the avoidance lever alone and possibly avoiding shock altogether or of continuing to maintain responding on the TO lever despite punishment.

A relevant factor should be the discrimination of the punishment shock from the shocks resulting from ineffective avoidance behavior. Since this discrimination would be most difficult when the animal is first faced with the problem a series effect might be expected. That is, if the animal is initially punished for the first response, the discrimination of this scheduled punishment as different from shocks which were not avoided must be made before suppression could appear. This discrimination should become easier the second time when the animal is punished for the middle or last response.

The effectiveness and stability of avoidance behavior should be an important factor in two ways. Its effectiveness should determine the aversive properties of the avoidance schedule, while its stability should influence the ease with which the animal could be expected to suppress on the FR lever and switch to the avoidance lever. Effectiveness of performance under the concurrent schedule should aid in discriminating pre-punishment and punishment conditions. Effectiveness of avoidance behavior and intensity of avoidance shock as compared with punishment shock would determine whether the animal would receive greater punishment by continuing to perform on the FR lever or by switching to the avoidance lever. Additional factors to be considered are the escape from conditioned aversive stimulation which the TO allows, and the amount of work requirement for the two alternative modes of response.

Punishment of a TOav schedule involves a greater complexity of variables than punishment of a straightforward FR schedule. This may lead to a greater difficulty in interpreting results and in producing consistent findings. However, it should also provide evidence concerning the effectiveness of TOav-reinforcement and perhaps make clearer the factors which are important in determining this effectiveness. Time out from avoidance has practical as well as theoretical value. Much of everyday behavior may be viewed as motivated by escape from anxiety-producing situations.

Method

Subjects

The subjects were four adult squirrel monkeys (*Saimiri sciureus*): G5, G6, G7, and G8. G5 was one of an earlier group of monkeys with which a different method was used for establishing the concurrent behavior required in the present experiment. He was the only one from the original group to continue in the experiment. He was naive, butthe method for stabilizing behavior was different for this animal. G6 and G7 were both naive. G8 had an earlier history of shock avoidance training in a restraining chair.

All animals were maintained together in one large enclosure, except for the time spent in the experimental chamber. Food pellets and water were present continuously in the enclosure and were supplemented frequently by fresh fruit and nuts. The colony was temperature (75°) and humidity (50%) controlled.

Apparatus

The equipment used in this experiment was the same as that described by Dalrymple (1968):

> "The experimental chamber was a Lehigh Valley Electronics small animal test cage (Model LVE 1417) situated within a ventilated, sound-attenuating cubicle. The grid floor consisted of 16 stainless steel rods, and was wired for the delivery of electric shocks to the feet of the subject. Two retractable rat levers (Model LVE 1405R) were mounted on one wall of the chamber, each 6 5/8 in. above the grid floor and separated by 5 3/4 in. Lever dimensions were 1 in. by 1 1/8 in. by 3/8 in. Six small stimulus lights were mounted on the wall of the test cage. These consisted of 2 red, 2 green and 2 white lights, one of each color being situated immediately above each lever. In addi-

tion, the chamber was fitted with a Chicago Miniature No. 304 28V dc houselight, and a 4 ohm speaker mounted within the cubicle, delivered "white noise" at an intensity of 75 db s.p.l. as measured by a Dawe Type 1400F sound level meter.....The experimental conditions were controlled automatically by a system of relays, stepping switches and timers located in an adjoining room. Data were recorded by an Elmeg print-out counter (Grason-Stadler Model E12505A), Sodeco digital counters, and by two Gerbrands cumulative-response recorders."

Two different constant current shock generators (Model LVE 1531) and a grid scrambler (Model LVE 131155) were used. One shock generator produced shocks as scheduled by the avoidance schedule. Except for the initial stages of training on the avoidance schedule, these shocks were consistently of a .5 seconds duration and at an intensity setting of 10 ma. The second shock generator produced shocks as scheduled according to the punishment conditions. The duration of these shocks was also .5 seconds, but intensity was varied between 1 and 12 ma. These shocks were programmed separately from the avoidance shocks and were generally of a different intensity. Circuits were arranged so that an avoidance shock could not be delivered at the same time as a shock occuring under the punishment conditions. The avoidance shocks were delivered following the absence of an avoidance (lever A) response for a specified length of time (TO-S=5 secs.[1], S-S=5 secs., R-S=20 secs.); punishment shocks were delivered following the completion of the specified number of FR responses on lever B.

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[1]The interval elapsing from the termination of a time out to the first scheduled shock, in the absence of an avoidance (lever A) response.

Procedure

Phase 1. Avoidance training on lever A.

Only one lever (lever A) was extended during avoidance training. For the first session the animal was allowed to adapt to the chamber for 15 minutes before experimental conditions were instated. At the end of this period, the houselight, white noise, and a white cue light over lever A came on, and a free-operant avoidance schedule of the Sidman (1953) type was put into effect. Under this schedule, a response on lever A reset the shock timer and postponed shock for 20 seconds (the response-shock interval). With no response, shocks occurred every 5 seconds (the shock-shock interval). Shock intensity for the first few sessions was 5 ma, with a duration of .5 seconds. After responding was established shock was increased to the final intensity of 10 ma. No signal preceeded shock and a response did not terminate a shock once it had begun. Daily session lengths were 4 hours for G5, 3 hours for G6 and G7, and 2 hours for G8. During earlier sessions animals were removed from the chamber if long blocks of shock, unbroken by a response, were received. Avoidance training was continued until responding was well established. Approximately 25 sessions of avoidance training were given all animals except G8. Since he had a prior history of avoidance training he was given only 10 avoidance sessions at the shorter 2 hours session length.

Phase 2. FR escape training on lever B.

G5: When avoidance behavior was well-established on lever A, training on the concurrent time out from avoidance (TOav) schedule began. Lever B was extended into the chamber and a white cue light similar to that above lever A was switched on. Otherwise stimulus conditions were the same as under the avoidance schedule. Lever A remained extended with the avoidance schedule still in effect. A fixed number of responses on lever B would produce a time out period of two minutes.

To prevent accidental reinforcement of the avoidance behavior by a TO, a 2 second change over delay (COD) requirement (Sidman, 1962) was added. A response on the TO lever (lever B) was effective only if 2 seconds had elapsed, timed from the last avoidance response. During the TO, shock delivery ceased, white cue lights, noise, and houselight were turned off, both levers were retracted, and green cue lights appeared above the retracted lever.

In an attempt to establish the FR behavior low FR values were used and the length of TO was varied unsystematically between 1 and 4 minutes. Under this procedure G5 continued to perform efficiently on lever A, but did not develop FR behavior on lever B. A new method (FR escape training) involving retracting lever A and extending lever B alone was tried. G5 began to develop concurrent behavior after this training and this method was used for all the subsequent animals to establish behavior under the concurrent schedule. Throughout the rest of the experiment the TO was one minute in length for G5 as well as for the rest of the animals.

G6, G7, and G8: After behavior had become stable on the free-operant avoidance schedule, lever A was permanently retracted and lever B alone was introduced into the chamber. The houselight, a white cue light, and white noise were present while lever B was extended. At the beginning of training animals had 5 seconds to fulfill the ratio requirement before shocks (10 ma, .5 secs.) were delivered at 5 second intervals. Later in the experiment the amount of time the animals had to fulfill the requirement before shocks began was changed to 20 seconds. This allowed larger ratio requirements during FR escape training without subjecting the animals to as great a number of shocks. When the required number of responses had been completed, lever B was retracted, houselight, noise and white cue lights were turned off, and a green light over the retracted lever was switched on. Under this changed stimulus complex, a one minute TO followed during which time shocks were never delivered. At the end of the TO period, the green light switched off, and pre-TO conditions were reinstated with white noise, houselight, and white light switched on. The shock timer was reset following each TO so that the animal again had 20 seconds to meet the response requirement before shocks were delivered.

Twelve sessions of FR escape training, two hours each in length, were given. The FR requirement was gradually moved up over sessions from 2 to 10. FR escape training was given regularly throughout the experiment whenever behavior had become suppressed by punishment.

Phase 3. The concurrent avoidance on lever A and FR escape on lever B schedule.

Following the separate avoidance and FR escape training on the two levers, the concurrent schedule was put into effect. Both levers were extended, and houselight, noise, and a white cue light over each lever were switched on. Now the animal could avoid shock by pressing lever A while accumulating responses on lever B in order to meet the ratio requirement. If no responses were made on lever A, shocks (10 ma., .5 secs.) occurred at regular 5 second intervals. Every response postponed the next scheduled shock for 20 seconds. A two second change over delay requirement was added to the schedule so that avoidance behavior could not be accidentally reinforced by a time out (as suggested by Sidman, 1962). Every avoidance response initiated this 2 second delay period during which time responses on the TO lever were ineffective. This procedure insured that a TO-reinforcement would not follow closely upon an avoidance response.

When the specified number of effective responses had been made on lever B, a one minute TO followed. Both levers were retracted, white cue lights, noise, and houselight were turned off, and a green cue light appeared over each lever opening. Following each TO the shock timer was reset so that the animal had 20 seconds before shock delivery was begun. Later during training the interval between the TO termination and first scheduled shock was changed from 20 seconds to

5 seconds. This was done because some animals were developing such a high rate of responding on the TO lever that the ratio requirement could be met within the 20 second period between TO-termination and first scheduled shock, with a consequent decline in responding on the avoidance lever. This change insured the maintenance of responding on the avoidance lever.

FR value was gradually moved up over sessions to the final value of FR 75. If FR responding was not maintained, the avoidance (lever A) was again withdrawn for a few days and a few additional sessions of FR escape training were given (Lever B).

Session length under the concurrent schedule was initially three hours. Later this was changed to 2½ hours or 50 TO's with the session ending either when the time had elapsed or when the TO's had been earned, depending on which occurred first. All animals easily earned 50 TO's within the time limit during this stage, although the amount of time taken differed considerably for fast and slow animals. Training was continued under the concurrent schedule until all animals had shown stable performance on the final parameters for at least 10 consecutive days.

Phase 4. Punishment.

This phase was the main objective of the research. After at least 10 consecutive days of stable performance on the concurrent TOav schedule, punishment of specific responses on the TO lever began. The FR value remained constant at 75, and every animal was punished for the first, middle, or last effective response of the ratio. It should be kept in mind that only effective responses contributed to the FR requirement, so that many responses made during the 2 second delay periods following avoidance responses might be emitted before the appropriate response could be punished. For all the punishment conditions, total number of responses preceding punishment would vary depending on the rate and pattern of avoidance responding.

Conditions under punishment were identical to those for training under the concurrent schedule, except for the punishment itself. Both levers were extended at the beginning of each session with white cue lights, noise, and houselight switched on. The avoidance schedule was the same with each response on lever A postponing shock for 20 seconds. Otherwise, 10 ma (.5 secs. duration) shocks occurred at 5 second intervals during active time.

Seventy-five effective responses on lever B earned a one minute TO from the avoidance schedule with levers retracted, white lights, noise, and houselight switched off, and green lights switched on. At the end of the one minute period, levers were extended and pre-TO conditions were reinstated. The TO-S interval (timed from the end of the TO to the first shock) was 5 seconds if no avoidance response was made. Each session was terminated either after 50 TO's had been earned or after 2½ hours. Punishment was delivered during the middle 30 TO's but not for either the first 10 TO's or for the last 10 TO's, if the animal earned these before the session ended.

Under each of the three punishment conditions a mild or moderate shock which would lead to some suppression of behavior was scheduled initially. Most animals first received a 1 ma shock; if suppression of TO-responding did not appear, shock intensity was increased at 4 day intervals until some decrease in response rate or change in response pattern was evident. The animal was then maintained for 10 days at this partially effective intensity. Ten days of recovery with no punishment of TO-responding followed. At the end of this period a more severe shock of at least 5 ma (and of greater intensity for animals which seemed resistant to suppression) was delivered. If complete suppression did not occur, intensity was again increased at 4 day intervals until the animal suppressed or had received the maximum (with the equipment used) punishment of 12 ma for 10 days. The specific effective response punished (either the first, the middle, or the last) remained the same from the initial exposure to punishment at a low intensity until after suppression. The animal was considered to have suppressed if fewer than 10 TO's were earned so that no punishment was scheduled. After 10 days under the suppressing intensity, animals were given 10 days with no scheduled punishment.

If recovery did not occur following punishment, FR escape training, with only lever B extended, was given for a few days in order to restabilize behavior under the concurrent schedule. Generally these sessions were two hours in length. The animal had 20 seconds (the TO-shock interval under these conditions) to complete the ratio requirement before the first shock was scheduled. The FR value was gradually increased to 25 or 30. This value was one which required a high rate but also one which animals could meet while receiving few if any shocks. After the necessary number of days of re-training on the TO lever the concurrent schedule was put into effect. Again at least 10 days of stable performance on the concurrent schedule was required before the next punishment conditions began. After restabilization the next FR response position (either the first, middle or last) was punished in the same manner as for the punishment of the prior response position. This was continued until each animal had received punishment under these conditions for all three of the FR positions.

Since series effects were expected, each animal was given a different order of punishment conditions. For the different animals the order was as follows:

SERIAL ORDER FOR ADMINISTRATION OF PUNISHMENT

G5 - FR 1, FR 75, FR 37
G6 - FR 37, FR 75, FR 1
G7 - FR 37, FR 1, FR 75
G8 - FR 75, FR 1, FR 37

Either the first effective response, the middle effective response, or the last effective response was punished in the orders given for the different animals. Only one punishment shock was scheduled during the completion of any given FR requirement. As mentioned earlier, the programming of punishment shocks was completely separate from the deliverance of shocks as scheduled by the avoidance schedule.

Phase 5. Extinction.

The effects of extinquishing the ratio schedule were determined for three of the animals. The concurrent schedule remained in effect for the first 10 time outs; for the 11th time out the TOav-reinforcement was removed. The session continued for the remainder of the 2½ hours with no reinforcement for lever B responding. The avoidance schedule remained in effect.

Behavioral Measurements:

Behavioral stability and changes in pattern of responding were determined both by an examination of the cumulative records and by data obtained from a Grayson-Stadler print-out counter. The following data were recorded after every time out: the total number of seconds taken to earn the last TO, the total number of avoidance responses during the last period of active time, and the total number of responses (effective plus ineffective) on the TO lever during the last period of active time. All of these data were necessarily obtained during active time; levers were retracted during TO precluding the possibility of responding.

From these data five measurements were determined:

1. The average number of avoidance responses per minute of active time.

2. The average number of responses on the TO lever per minute of active time. This is including both effective and ineffective responses.

3. The average time taken to earn a TO.

4. The average number of ineffective FR responses made for the earning of a TO. The ineffective responses, as explained previously, are those which occur during the 2 second COD and do not contribute to the completion of the FR 75 requirement.

5. The average number of avoidance responses made for the earning of a TO.

These measurements were calculated separately for the first 10 TO's, for the middle 30 TO's during which FR responding was punished, and for the last 10 TO's. Cumulative records were obtained separately for avoidance responses and for responses on the TO lever. The cumulative recorder had a constant paper speed of 30 cm/hr. and a stepping distance for the pen of four responses per millimeter. Each recorder had a maximum excursion of 500 responses, after which the pen automatically reset. Paper drive stopped during TO periods. Shocks which occurred under the avoidance schedule were represented by oblique deflections of the pen on the avoidance record. A time out period was represented by an oblique deflection of the pen on the record of TO responses. The scheduled punishments of FR responding were not marked on the cumulative records.

Results

AVOIDANCE TRAINING

The gradual increase in response rate and decrease in shock rate for all animals as avoidance training progressed is shown in figure 1. Because of prior experience G8 required only 12 days of 2 hour sessions rather than the 25 days given the other animals. G5 had 4 hour sessions, and session length for G6 and G7 was 3 hours.

Because animals were started in the experiment at different times, conditions during training on lever A varied. By the end of avoidance training responding on lever A was well established for all animals (figure 2). Most of G5's training was under the parameters R-S=20, S-S=5, but a change was made for a few of the later sessions to R-S=S-S=10. The records shown for G5 in figure 2 is from one of these later sessions, and the parameter change probably accounts for the high response rate and shock rate. In spite of the fewer and shorter sessions for G8, response and shock rates at the end of training were comparable to those of the other animals.

For most of the animals, rate on the avoidance lever was still increasing at the end of this stage.

ESCAPE TRAINING

Representative records obtained under escape training when lever B alone was extended are shown in figure 3. Again, procedures varied between animals. The time between TO termination and the first scheduled shock was changed from 5 seconds to 20 seconds for G8. This allowed the establishment of a higher FR requirement while still giving the animal time to avoid shocks by producing a time out. The avoidance lever (lever A) was retracted during this stage. Table I shows the number of sessions, the total shocks obtained and the number of time out periods earned in each session. The FR requirement was increased gradually between sessions and within sessions: from FR 2 to FR 10 for G5, G6, and G7: from FR 2 to FR 30 for G8.

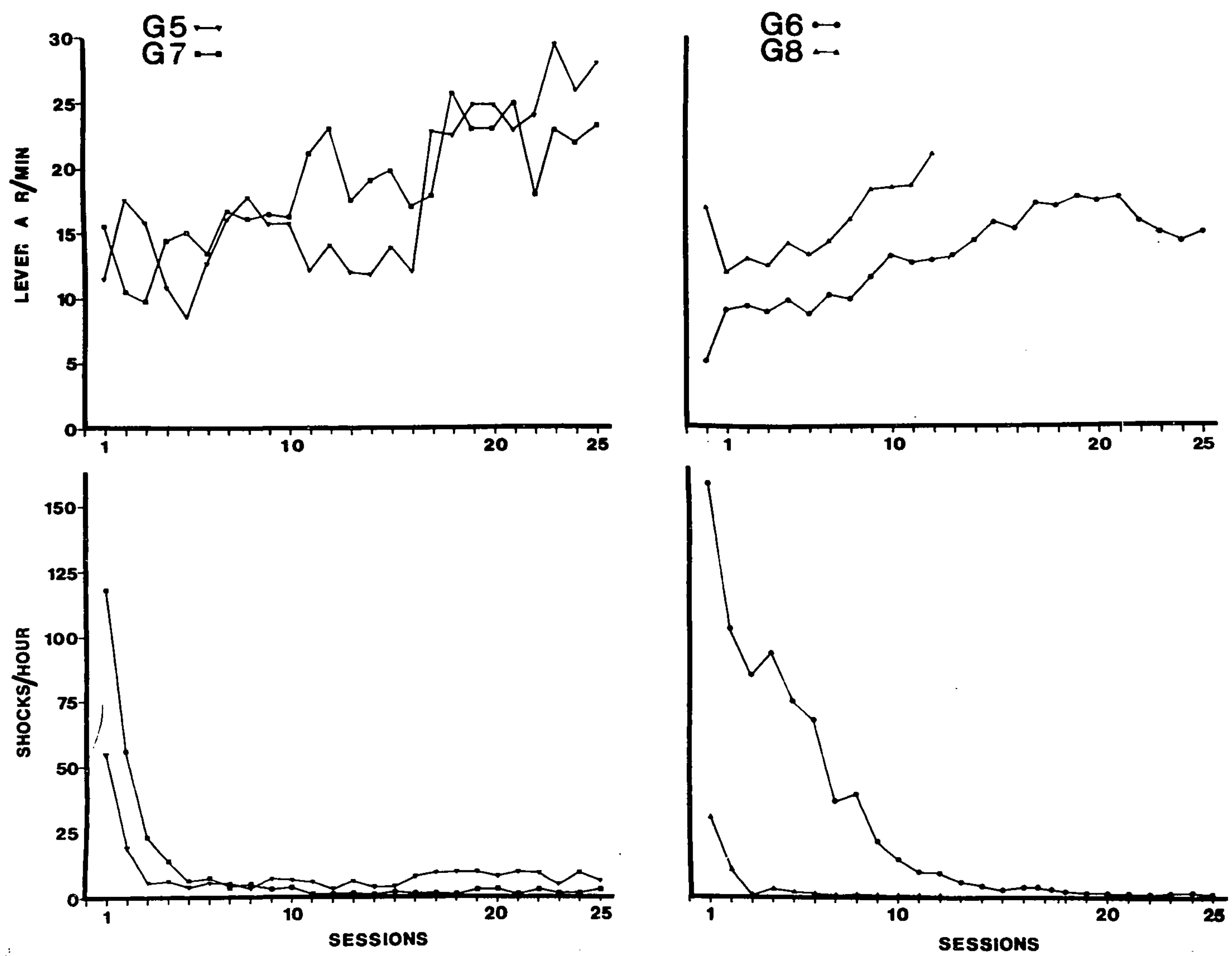
G5
G7
G6
G8
LEVER A R/MIN
SHOCKS/HOUR
SESSIONS
SESSIONS

Fig. 2. Selected cumulative response records for each subject showing behavior engendered by the free-operant shock avoidance training (lever A). Oblique downward deflections of the pen indicate shock deliveries.

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Fig. 1. Graphs showing the lever A responses per minute and the shocks per hour of each animal during avoidance training.

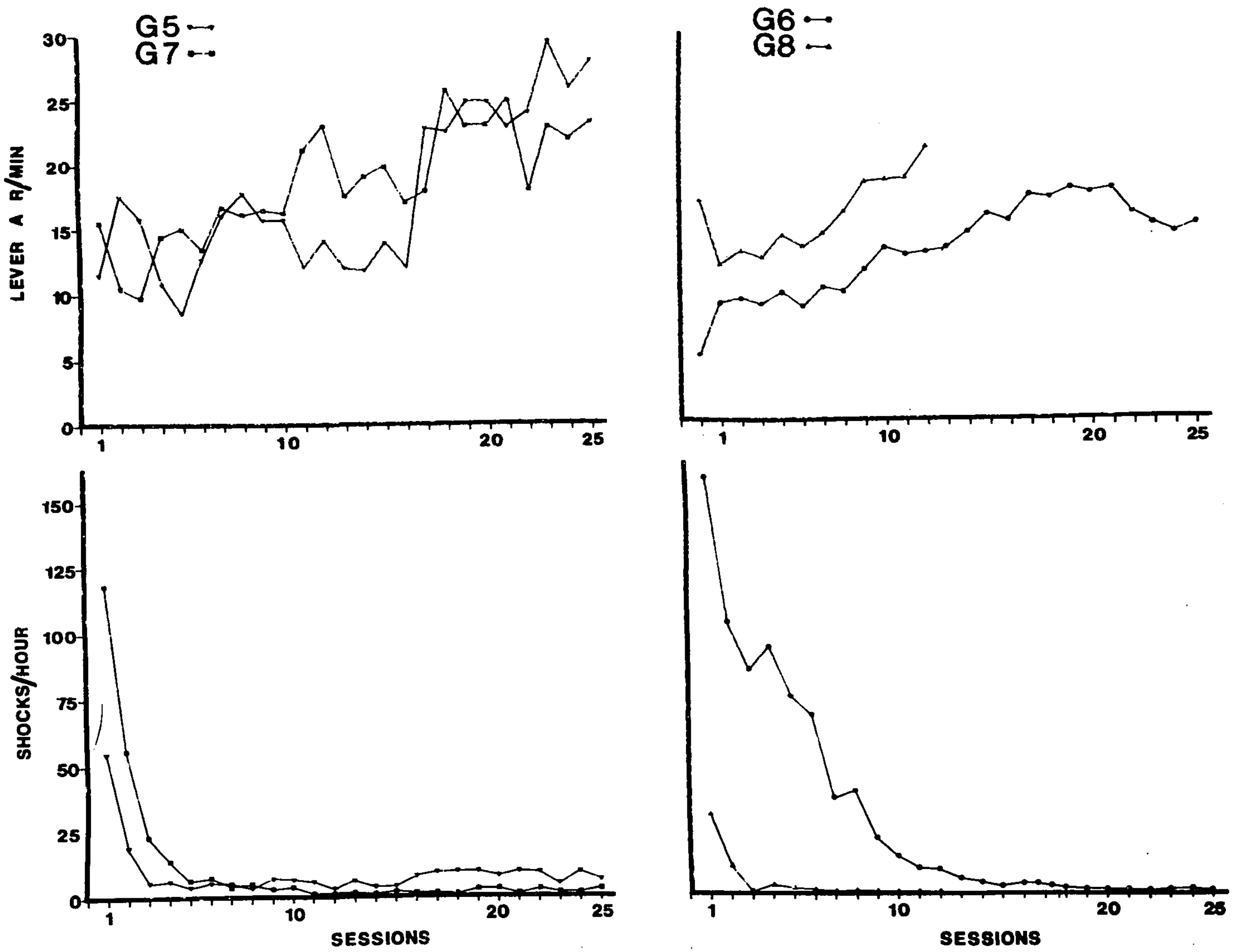
G5
G7
G6
G8
LEVER A R/MIN
30
25
20
15
10
5
0
1
10
20
25
SHOCKS/HOUR
150
125
100
75
50
25
SESSIONS

Fig. 2. Selected cumulative response records for each subject showing behavior engendered by the free-operant shock avoidance training (lever A). Oblique downward deflections of the pen indicate shock deliveries.

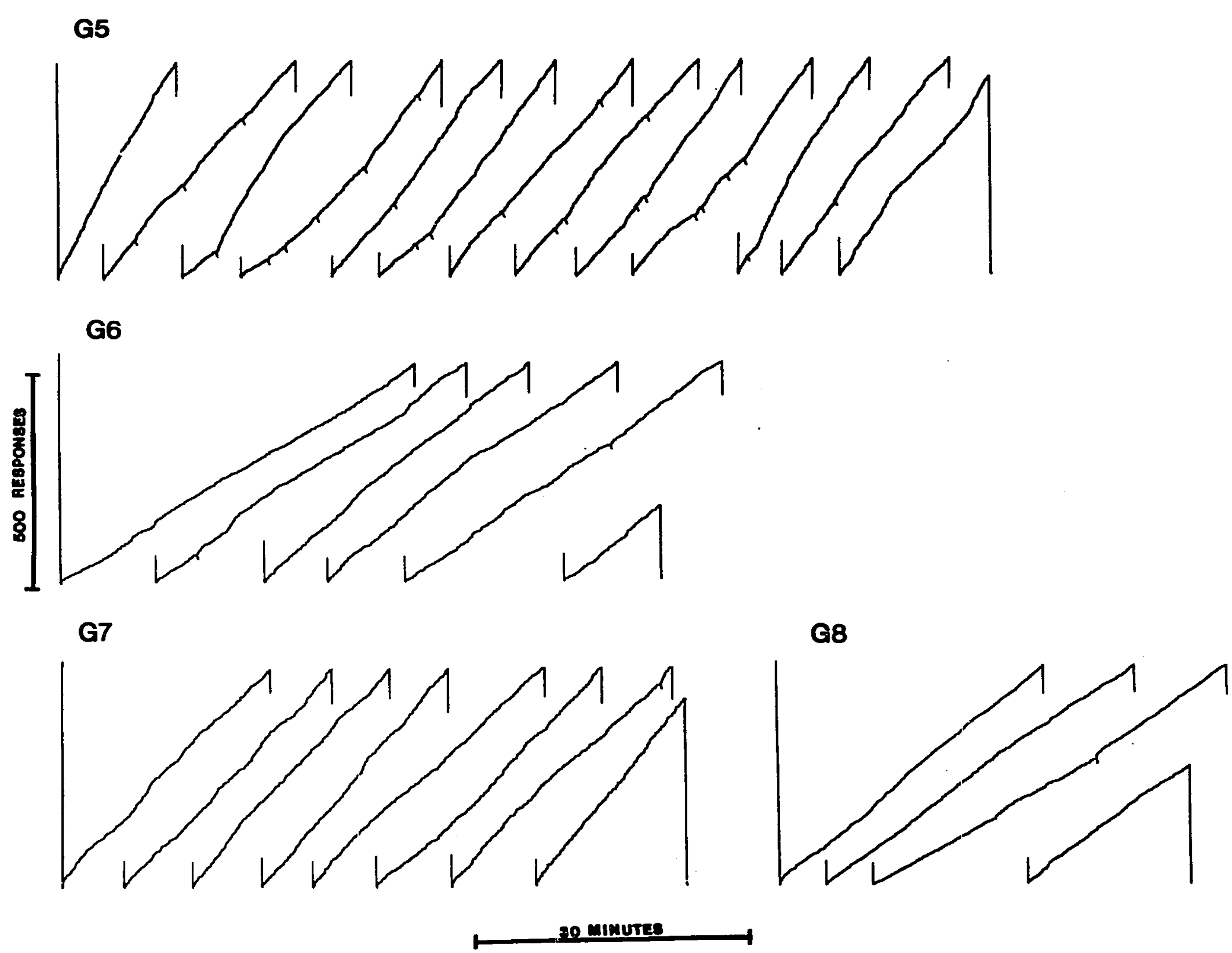
G5
G6
500 RESPONSES
G7
G8
30 MINUTES

Fig. 3. Representative cumulative response records showing the performance of each subject during FR escape training. The FR requirement is 10 for G5 and G6; 8 for G7; and 30 for G8. Oblique downward deflections of the pen indicate periods of time out initiated by the responses of the subjects; the paper drive was halted during each time out period.

FR ESCAPE TRAINING

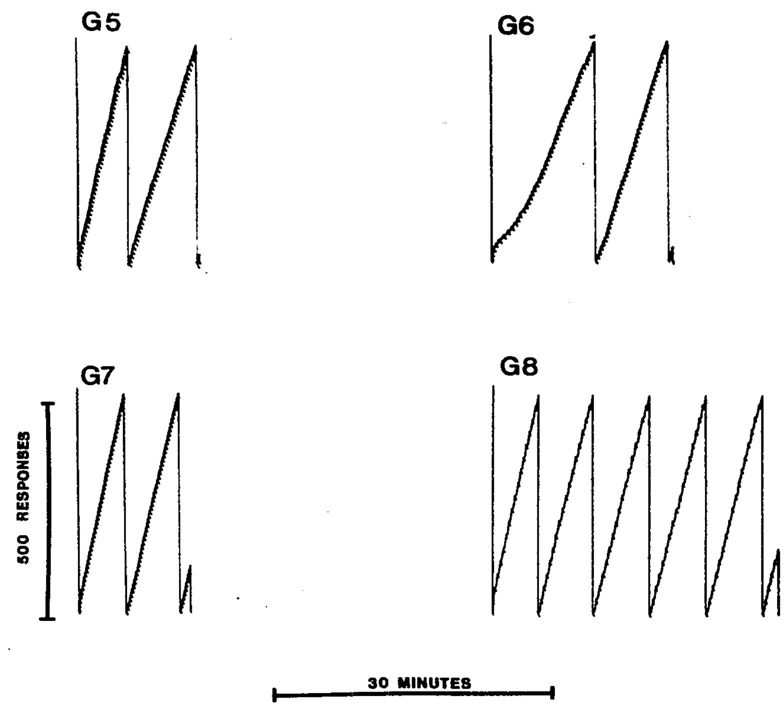

TABLE I

	G5		G6		G7		G8	
	No. TO's	TOTAL SHOCKS	No. TO's	TOTAL SHOCKS	No. TO's	TOTAL SHOCKS	No. TO's	TOTAL SHOCKS
1	108	103	108	79	109	104	92	21
2	112	69	106	101	109	106	152	5
3	111	88	109	106	111	67	135	7
4	105	69	108	102	111	78	92	9
5			107	100	111	67	90	22
6			109	121	111	69	88	41
7			106	134	112	71	87	61
8			106	126	111	74	86	82
9			103	176	111	73	88	31
10			103	176	112	76	88	25
11			103	171	112	67	92	2
12			103	186	112	74	91	1

CONCURRENT SCHEDULE

After FR escape training (lever B), both levers were extended into the experimental space and training under the concurrent schedule began; the FR requirement to produce TO was increased gradually over a number of sessions to FR 75. The avoidance schedule (lever A) parameters remained unchanged. As the FR requirement was increased, responding on lever B was, on occasion, poorly maintained and the monkey responded on lever A alone. On these occasions either the FR requirement was decreased or the conditions of FR escape training were reinstated. Monkeys G5 and G6 reached the FR-75 requirement in approximately 60 sessions; G7 and G8 responded at a higher FR rate and required fewer (approximately 20) sessions. After responding was maintained for a time at the FR-75 ratio requirement, both G7 and G8 began to respond minimally on the avoidance lever (lever A). To insure that lever A responding would not cease entirely, the TO-S interval[1] was changed from 20 seconds to 5 seconds. While the two animals (G7 and G8) with high response rates on lever B could make 75 responses within the 20 second TO-S interval, neither was able to complete the 75 responses within 5 seconds; in order to avoid shock at least one lever A response following every TO was necessary.

G5, G6, and G7 were maintained on the concurrent schedule for several months before the punishment procedures were begun. G8 was brought into the experiment at a later date after the loss of a previous animal and was maintained on the concurrent schedule for a shorter period of time.

Figure 4 shows representative cumulative records of stable performance for the four animals during the last 10 days of training before punishment conditions. G7 and G8 responded at a high rate on lever B and a low rate on lever A. G5 and G6 maintained higher rates on lever A and switched more frequently between levers. For these animals, rate on lever B was low following a time out, and runs of lever B responding tended to become longer as the FR requirement neared completion. An unusual effect of deceleration of responding, sometimes referred to as a "knee", immediately following a time out occasionally appeared in the record of G5 (figure 4). This knee was followed, however, by the more typical pattern of runs which increased in length until the time out was earned.

Lever A and lever B responses per minute, the mean number of extra (or ineffective) responses on lever B per TO, and the average time (in seconds) taken to earn a time out are given for the 10 days of performance preceding the beginning of punishment conditions in

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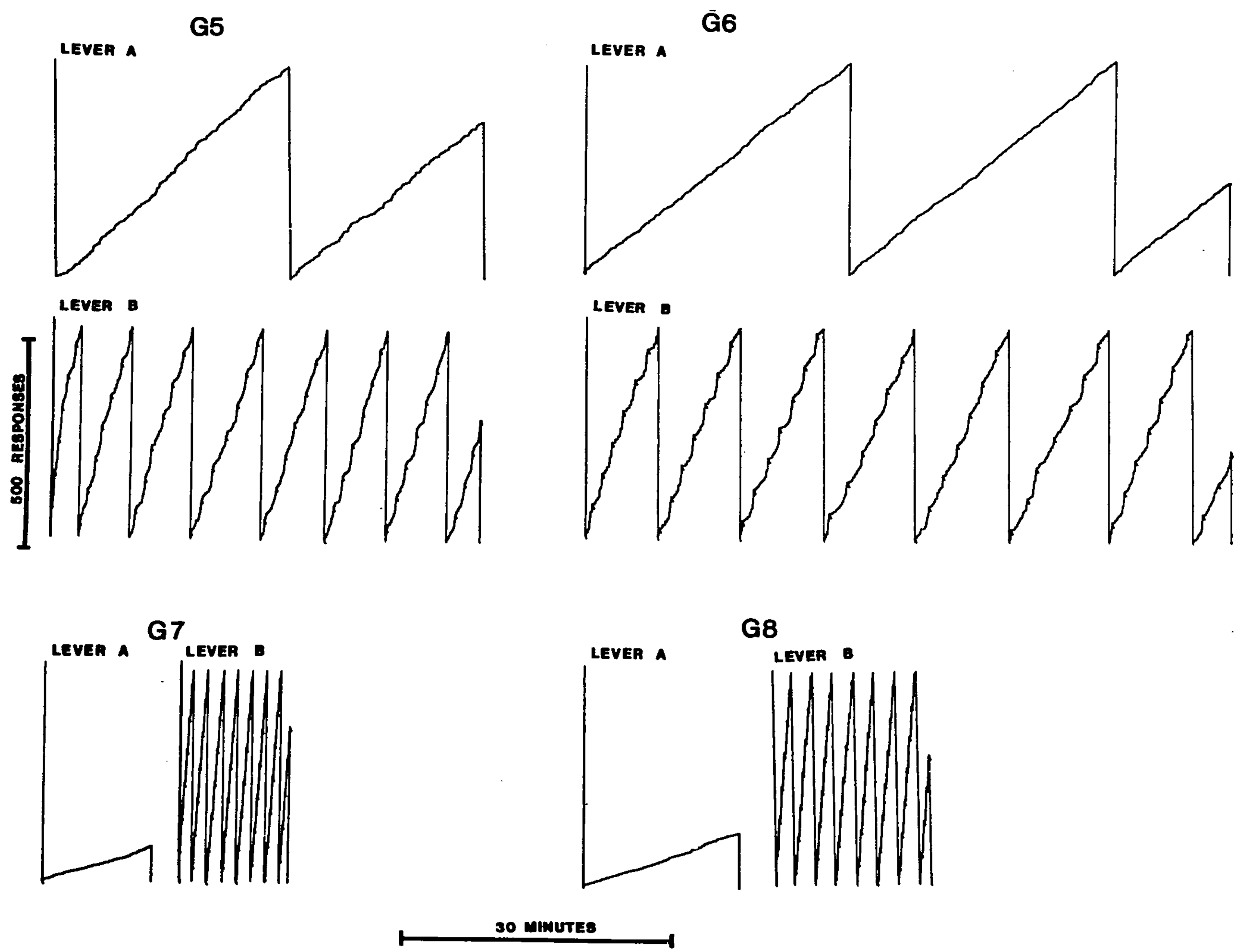
[1]The interval elapsing from the termination of a time out to the first scheduled shock, in the absence of an avoidance (lever A) response.

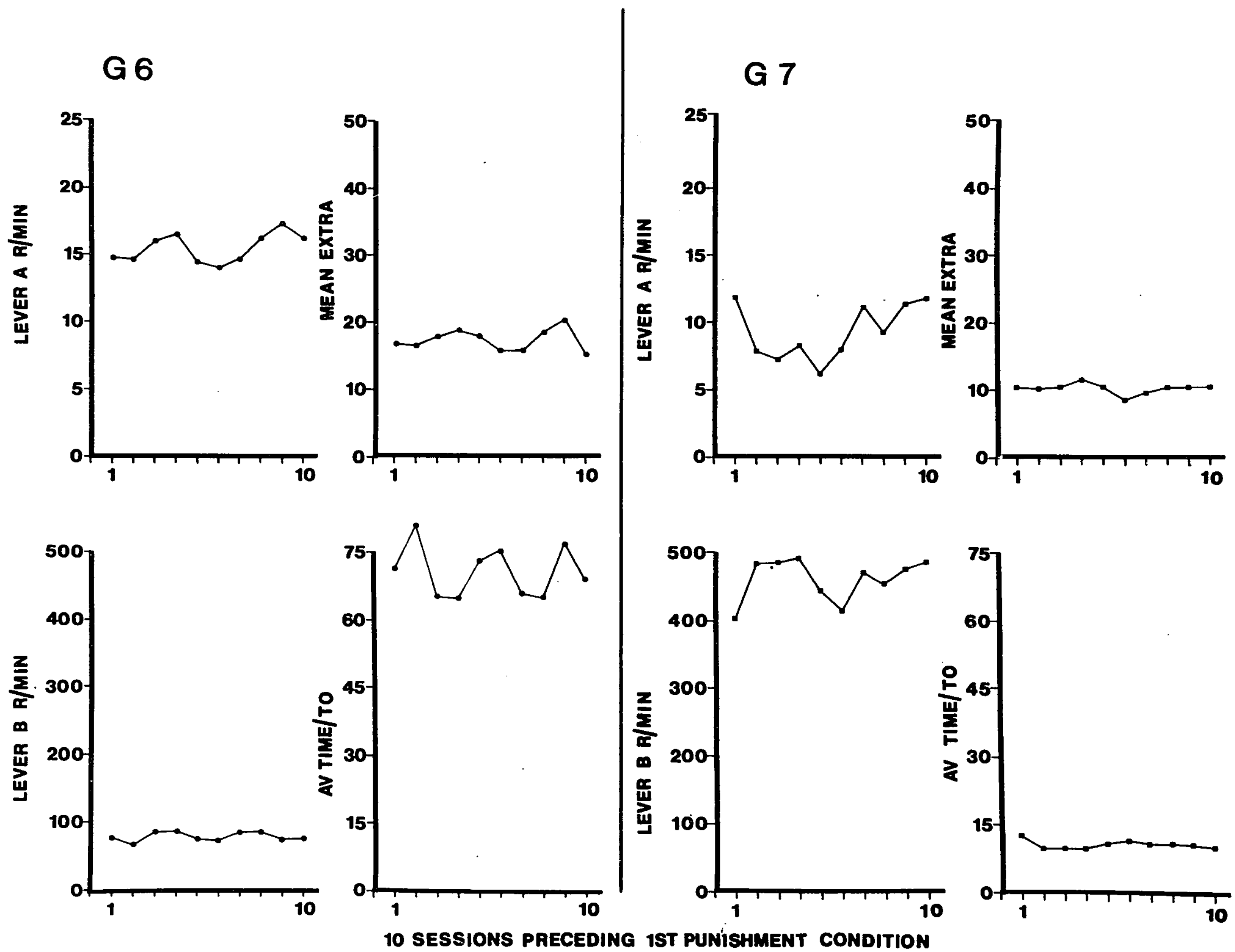
Fig. 4. Cumulative records obtained from each subject following stabilization of performance on the final parameters of the concurrent schedule (free-operant avoidance/FR 75 escape). Lever A records show performance on the free-operant avoidance component of the schedule; lever B records show performance on the FR escape component. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.


G5
LEVER A
LEVER B
G6
LEVER A
LEVER B
500 RESPONSES
G7
LEVER A
LEVER B
G8
LEVER A
LEVER B
30 MINUTES

figures 5 and 6. Avoidance rates varied between 16 and 23 for G5, 14 and 17 for G6, 7 and 12 for G7, and 7 and 11 for G8. This amount of variation for each animal is small, and rates were quite stable. Variation was greater both between animals and within animals for rate on lever B. Lever B rate varied between 132 and 168 for G5, 72 and 87 for G6, 402 and 491 for G7, and 234 and 274 for G8. The lever B rates for G5 and G6 seemed more similar on the cumulative records. However, G5 made a greater number of responses during the 2 second COD which were ineffective and did not appear on the cumulative records. This accounts for the higher total rate for G5. G6 tended to pause after responding on lever A and emitted fewer lever B responses which fell within the 2 second COD (change over delay).

The time taken to earn a TO is more clearly related to FR responding as recorded on the cumulative record than rate of response (which includes effective and extra responses). Mean time to earn a time out varied between 39 and 66 seconds for G5, 65 and 77 seconds for G6, 10 and 13 seconds for G7, and 17 and 19 seconds for G8. Note that the extremes of variation in time were within a few seconds of each other for both of the high rate animals. The most variation was shown by G5 who also emitted the greatest number of mean extra response. There is a striking correspondence between measures of mean extra responses and the average time to complete a TO for G5 (figure 6). Correspondence between these measures was not obvious for the other animals. As would be expected, an inverse relationship existed between rate on lever B and the average time taken to earn a time out for all animals. There was also a tendency for the number of ineffective (mean extra) responses on lever B to increase as lever A rate increased. This is understandable since every response on lever A reinstated the 2 second COD during which time lever B responses were ineffective.

Fig. 5. In the graphs lever A responses per minute, lever B responses per minute, mean extra responses, and the average time (in seconds) per time out are plotted for G6 and G7 for the 10 sessions preceding the first punishment condition. Each point represents an average value for a single experimental session.



G 6
G 7
LEVER A R/MIN
MEAN EXTRA
LEVER B R/MIN
AV TIME/TO
25
20
15
10
5
0
50
40
30
75
60
45
500
400
300
200
100
1
10
10 SESSIONS PRECEDING 1ST PUNISHMENT CONDITION

Fig. _6_. In these graphs lever A responses per minute, lever B responses per minute, mean extra responses, and the average time (in seconds) per time out are plotted for G8 and G5 for the 10 sessions preceding the first punishment condition. Each point represents an average value for a single experimental session.

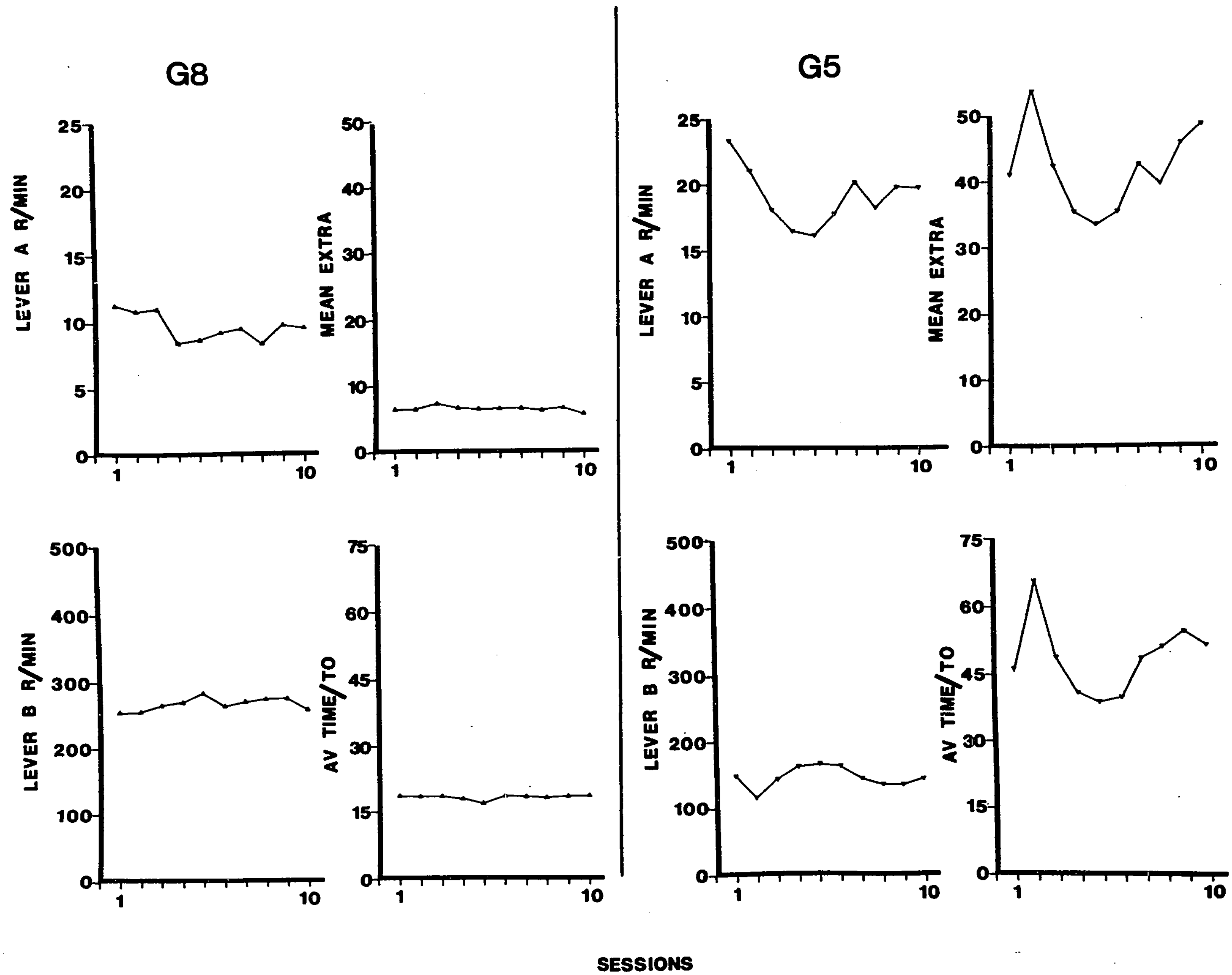

G8
G5
LEVER A R/MIN
MEAN EXTRA
LEVER B R/MIN
AV TIME/TO
SESSIONS

TABLE II

Serial Order for Administration of Punishment

Animal	FR-1	FR-37	FR-75
G5	1	3	2
G6	3	1	2
G7	2	1	3
G8	2	3	1

FR-1 PUNISHMENT

The effects of punishing the first response of the ratio requirement were strikingly consistent among animals. The first 10 ratios were never punished, so performance at the beginning of the session was little effected. Suppressive effects consistently appeared in the form of pausing after a time out. A scattering of single responses on lever B were occasionally emitted which fell within the 2 second COD and therefore did not contribute to completion of the ratio. After the first effective lever B response was punished, the remainder of the ratio was completed at a high rate. Frequently no pausing or switching between levers occurred during the high terminal rate responding even in animals who had shown considerable switching in their prepunishment performance.

Figures 7, 9, 11, and 13 give the lever B rate, the lever A rate, the number of time outs earned during the session, and the number of ineffective (mean extra) responses. When the sessions are numbered consecutively this indicates that recovery occurred completely after mild punishment and no stabilization procedures were required before a higher intensity of punishment was employed. Sample cumulative records are shown in figures 8, 10, 12 and 14.

G5: In figure 7 data are shown for G5 for the 10 days preceeding punishment, 10 days of 1 ma punishment, 10 days with punishment removed, 5 days of punishment under 5 ma, and 10 days following the punishment. Recovery was rapid and complete following the mild punishment. No recovery occurred following 5 ma punishment. Several features of the punishment procedure are apparent in figure 7. The punishment effects are not immediate but gradual. For the first few days most of the 50 time outs are earned within the $2\frac{1}{2}$ hour session. The rate on lever B and the number of time outs earned gradually decrease over the 10 days of 1 ma punishment. There is a corresponding increase in rate of responding on lever A. Recovery of lever B rate occurs after punishment is removed, accompanied by a corresponding decline in lever A rate until both rates are again stabilized at prepunishment levels. Under 5 ma punishment the suppression of lever B responding and increase in lever A rate was more rapid. Recovery of prepunishment rates did not occur on either lever A or lever B.

Representative cumulative records prior to punishment and under the 1 ma and 5 ma conditions are shown in figure 8. The effects of FR-1 punishment will be described in more detail for G5 than for the other animals. Since results were similar for all animals, repeating all the details would involve a lot of duplication.

The stabilized record preceding the punishment conditions (figure 8-prepunishment) showed deceleration on the avoidance record (lever A) within each period of active time, giving an inverse "scalloped" effect to the record. The FR record typically revealed an increase in rate toward the end of the ratio, corresponding to the deceleration of lever A rate.

On the first day of FR-1, 1 ma punishment, smoothness and consistency of the decelerations on the avoidance record improved. Little change was apparent in the FR record. During the 2nd day of punishment,

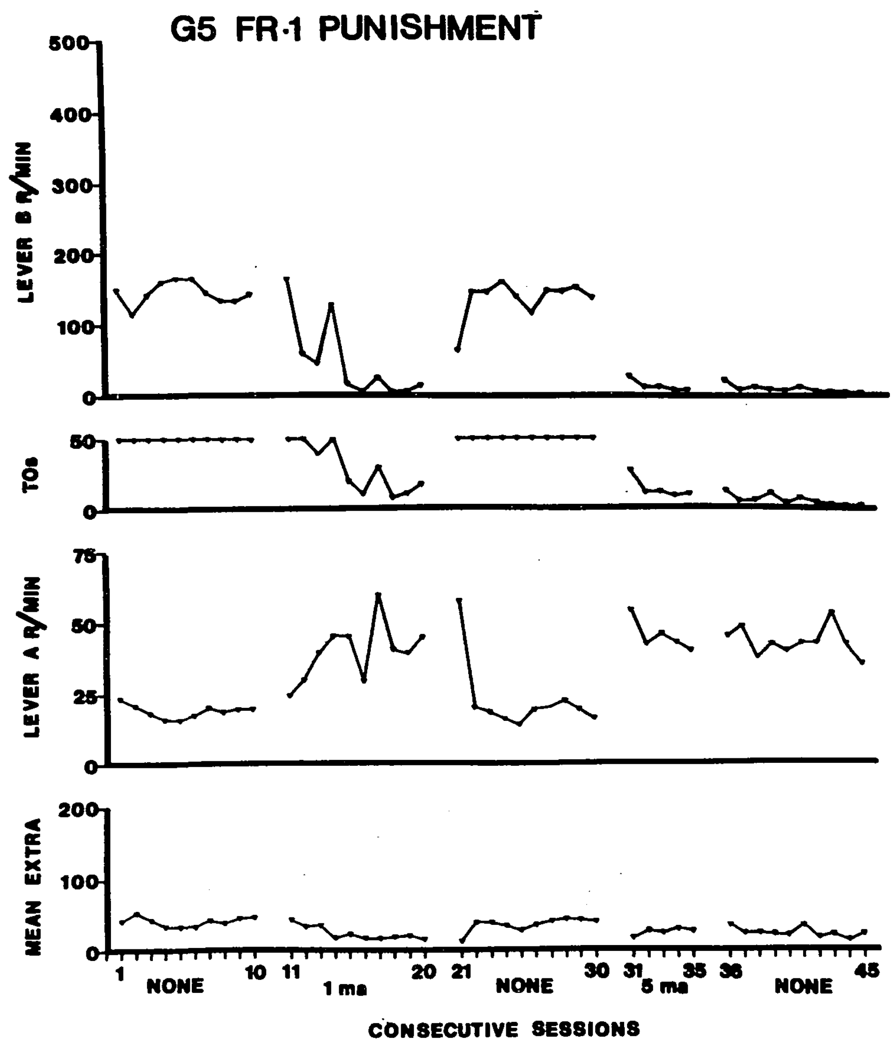
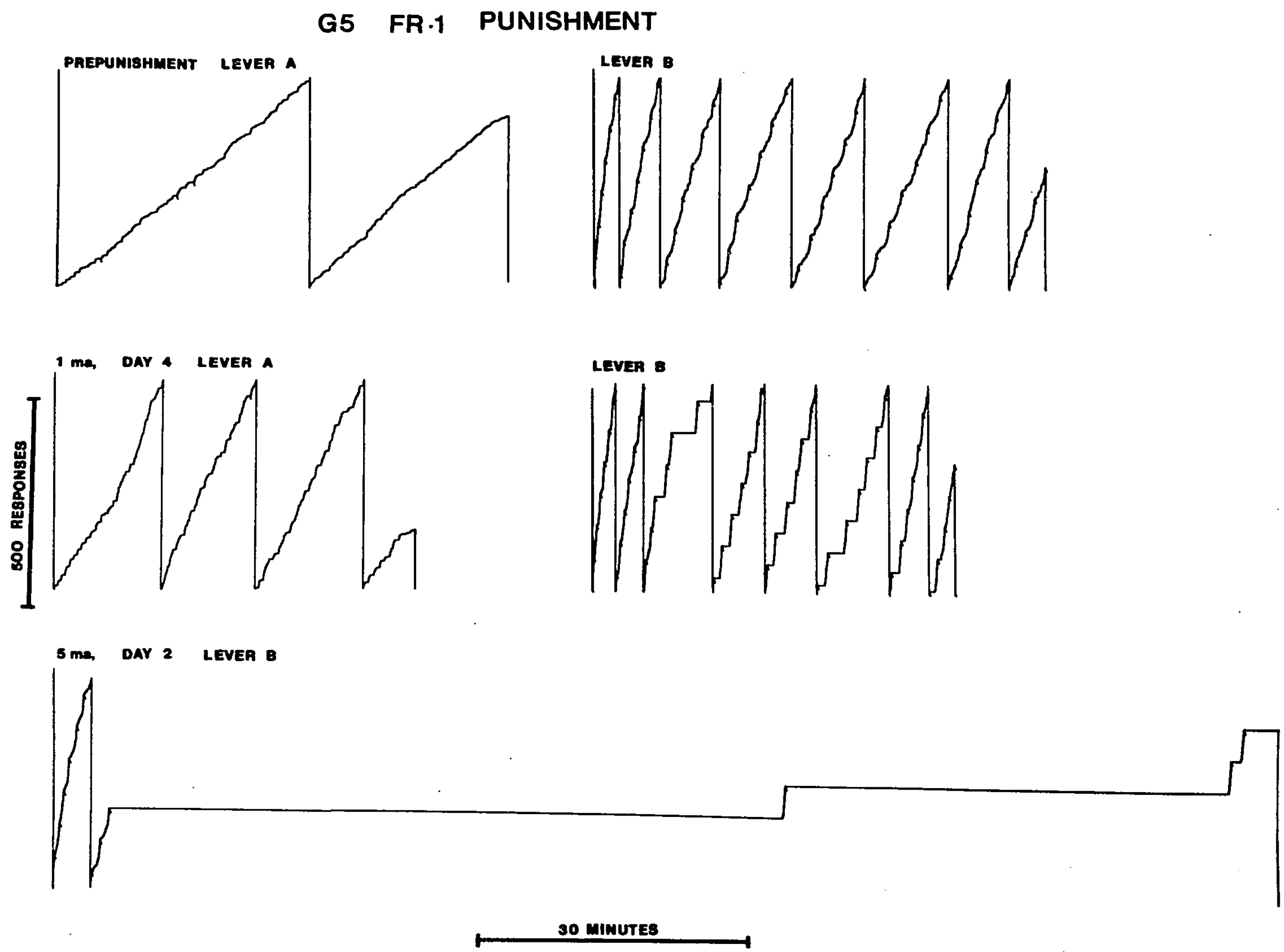

G5 FR·1 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1
NONE
10
11
1 ma
20
21
NONE
30
31
5 ma
35
36
NONE
45
CONSECUTIVE SESSIONS

Fig. 8. Representative cumulative records are shown for G5 during FR-1 punishment. The upper records are of prepunishment performance on lever A and lever B. The middle records show responding on lever A and lever B for the fourth session of 1 ma shock; the lower record shows performance for the second day under 5 ma shock on lever B. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.


G5 FR·1 PUNISHMENT
PREPUNISHMENT LEVER A
LEVER B
1 ma, DAY 4 LEVER A
LEVER B
500 RESPONSES
5 ma, DAY 2 LEVER B
30 MINUTES

however, this effect on the lever A record disappeared. On the lever B record pauses occurred following a time out. After these pauses, when the first response (the punished one) occurred the required 75 responses were immediately run off at a rate much higher than under prepunishment conditions. Frequently not a single break or switch to the avoidance lever occurred until the 75 responses were completed. The post reinforcement pauses continued to appear during the last 10 time outs when no punishments were scheduled. A much higher lever A rate emerged. This is very apparent in the graph shown in figure 7. Lever A rate increased under mild punishment, decreased to the previous level after punishment was removed, and again increased after more intense shock was introduced.

On the fourth day (figure 8-1 ma, day 4) recovery occurred with post reinforcement pauses of short duration appearing. As in the preceding sessions rate of responding, once it had begun, was much higher than before punishment. Frequently no breaks occurred after responding was initiated. For the middle portion of the avoidance record, relatively high rates followed by short breaks (at which time rapid FR responding occurred) were typical. A comparison of the lever A record before punishment with the lever A rate for the fourth day of 1 ma shock (shown in figure 8) makes apparent the marked increase on lever A after the introduction of punishment.

By day 10 a greater degree of suppression had again occurred, with only 17 time outs earned during the session. Twelve of these were at the beginning of the session and were above the prepunishment rate. The others followed long post-TO pauses and were completed at a high uninterrupted rate.

On the first day following 1 ma punishment recovery began. During the middle of the session the long pauses characteristic of previous sessions appeared, but later in the session these pauses became shorter and then disappeared. Thirty-one time outs were earned. By day 2 recovery was complete, with regular and smooth periods of deceleration appearing on the avoidance record. No post reinforcement pauses occurred on the FR record and the prepunishment characteristics of performance reappeared.

Under FR-1 punishment of 5 ma, suppression was more rapid, During day 2 only 12 time outs were earned (figure 8 - 5 ma, day 2). The earlier consequences of FR-1 punishment at lower intensities reappeared. The decelerations on the avoidance record during time in periods disappeared except at the beginning of the session, and rate increased. On the FR record long post-TO pauses appeared followed by a rapid completion of the 75 required responses.

As mentioned earlier, in the 10 sessions following punishment of 5 ma, recovery did not take place. Eight days after punishment had been removed only two time outs were earned.

G7: G7 received FR-1 punishment as the second punishment condition. In figures 9 and 10 data and cumulative records are shown. Figure 9 shows a gradual suppression on lever B under 1 ma shock, with the exception of partial recovery on day 6. Except for a brief initial increase in rate of responding on lever A, punishment produced a decrease in rate on lever A which persisted through restabilization of performance. However, the prepunishment performance for FR-1 punishment was higher than it had been prior to the first punishment condition. Following FR-1 punishment rate became comparable to that existing before the first punishment condition (FR-37). Partial recovery occurred following removal of the 1 ma punishment. The 50 TO's were completed within all of the sessions but considerable suppression of lever B rate remained.

Restabilization procedures were used before the introduction of 5 ma shock. Progressing along the abscissa of figure 9 the initial 10 sessions are the prepunishment stabilized performance, sessions 11 to 20 are under 1 ma shock, and sessions 21 to 30 are post-punishment sessions. The sessions are then numbered starting from 1

Fig. 9. In these graphs lever B response per minute, number of time outs earned during the session, lever A responses per minute and the average number of extra responses per time out are plotted for G7 for the FR-1 punishment condition. Each point represents a value for a single experimental session. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma punishment shock (sessions 11 through 20), and following punishment (sessions 21 through 30). Restabilization intervened before the introduction of higher intensity shock. The next values are before punishment (sessions 1 through 10), during 5 ma shock (sessions 11 through 14), during 9 ma shock (sessions 15 through 18), during 12 ma shock (sessions 19 through 28) and following punishment (sessions 29 through 38).

G7 FR·1 PUNISHMENT

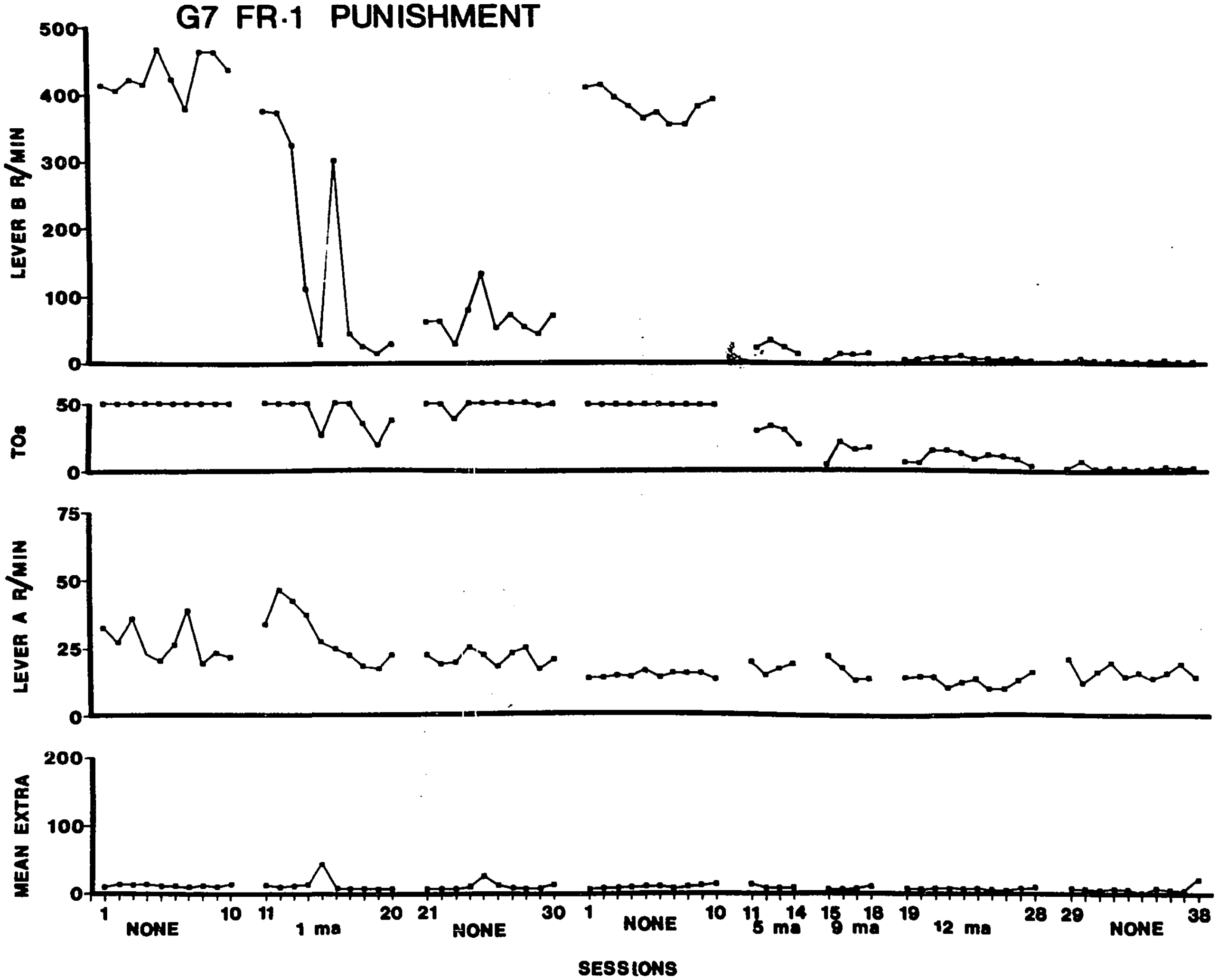
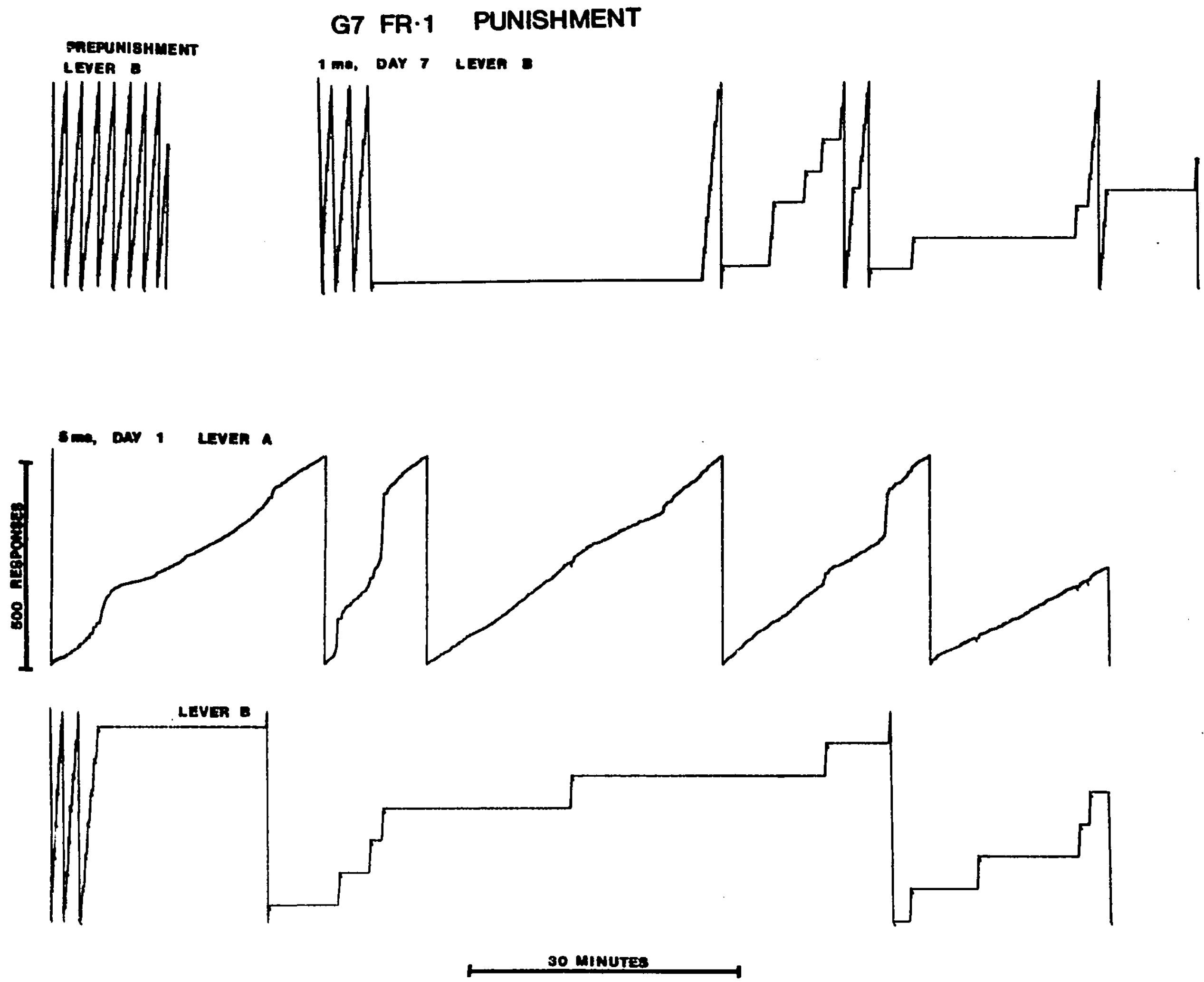


Fig. 10. Representative cumulative records are shown for G7 during FR-1 punishment. The upper records are of prepunishment lever B performance and lever B performance on the 7th day of 1 ma shock. The middle record shows lever A responding and the lower record lever B responding for the first day of 5 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.



G7 FR·1 PUNISHMENT
PREPUNISHMENT
LEVER B
1 ms, DAY 7 LEVER B
5 ms, DAY 1 LEVER A
500 RESPONSES
LEVER B
30 MINUTES

again, since restabilization procedures intervened. The second grouping of sessions 1 to 10 are those immediately preceding the 5 ma shock conditions. Introduction of 5 ma shock produced immediate suppressive effects. Since suppression was not complete after four days of 5 ma shock followed by four days of 9 ma shock, 10 sessions of punishment under 12 ma shock were given. Complete suppression resulted and continued after punishment was removed.

Figure 10 shows representative cumulative records for prepunishment performance, lever B performance under 1 ma punishment, and lever A and B performance under 5 ma.

Under FR-1 punishment (1 ma) the bursts of lever A responses preceding lever B responding increased in length. On lever B the post-TO pauses increased in length accomodating the longer lever A bursts. By day 5 lengthy post-TO pauses preceded the first lever B response. On the avoidance record an unusual pattern emerged. Rate was relatively low and uniform during a pause on lever B; then, immediately preceding a resumption of lever B responding, a rapid burst of lever A responses would occur followed by a rapid completion of the 75 lever B responses. When avoidance shocks occurred these typically initiated a burst on lever A followed by a run on lever B earning another TO. The avoidance record is not shown for 1 ma, day 7 punishment because of lack of space. However, these features are apparent on the record for 5 ma, day 1 (figure 10). During the first prolonged pause on lever B, the rate on lever A gradually leveled. A small burst on lever A preceded the next ratio run. Another pause appeared before the initiation of lever B responding. Before responding was resumed on lever B for the second time a rapid run of responses, characteristic of lever B rate, occurred on lever A. The high rate was then transferred to lever B. It looked as if the animal began the run on lever A and completed it on lever B. This unusual pattern appeared clearly three times on the record shown, and was common on all the records under FR-1 punishment for this animal. It did not appear under any of the other punishment conditions. An examination of the same record (figure 10-5 ma, day 1) also shows ratio runs which were elicited by shock programmed on the avoidance schedule. Practically all ratios completed following the first pause on lever B were either preceded by a run of responses on lever A or were initiated by shocks (recorded on the avoidance record).

The most representative feature of these records obtained under FR-1 punishment for G7 is, of course, the prolonged post-reinforcement pauses on lever B. The lever B records for G7 correspond strikingly with the records obtained for G5, in spite of the large individual differences in prepunishment stabilized performance.

G8: The findings for G8 (figures 11 and 12) present something of a problem since suppression was not obtained even under 12 ma punishment. FR-1 punishment was the second condition for this animal and suppression was not obtained for the first condition (FR 75 punishment) either. Figure 11 shows that a small decrease in lever B rate was accompanied by an increase in lever A rate under punishment. An initial effect of punishment which gradually disappeared was a marked increase in shock rate under the avoidance program. This is apparent in figure 12, 2 ma punishment, day 1. Note that the punishment shocks were of a low intensity (2 ma), while the shocks incurred as a result of failure to avoid were 10 ma. The emphasis was on escape behavior (to produce the time out) with a neglect of lever A avoidance responding. By day 7 the animal was again efficiently avoiding shocks with a heightened rate on lever A. The final pattern (figure 12-12 ma, day 2) of lever A responding was one of a low rate during the initial 10 unpunished periods, a heightened rate during the middle punished section, and a resumption of the lower avoidance rate for the last 10 unpunished periods. Little suppression occurred on lever B.

Fig. _11_. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G8 for the FR-1 punishment condition. Each point represents a value for a single one of the 63 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 2 ma shock (sessions 11 through 20), following punishment (sessions 21 through 30), during 5 ma shock (sessions 31 through 35), 7 ma shock (sessions 36 through 39), 9 ma shock (sessions 40 through 43), 12 ma shock (sessions 44 through 53) and after punishment (sessions 54 through 63).

G8 FR·1 PUNISHMENT

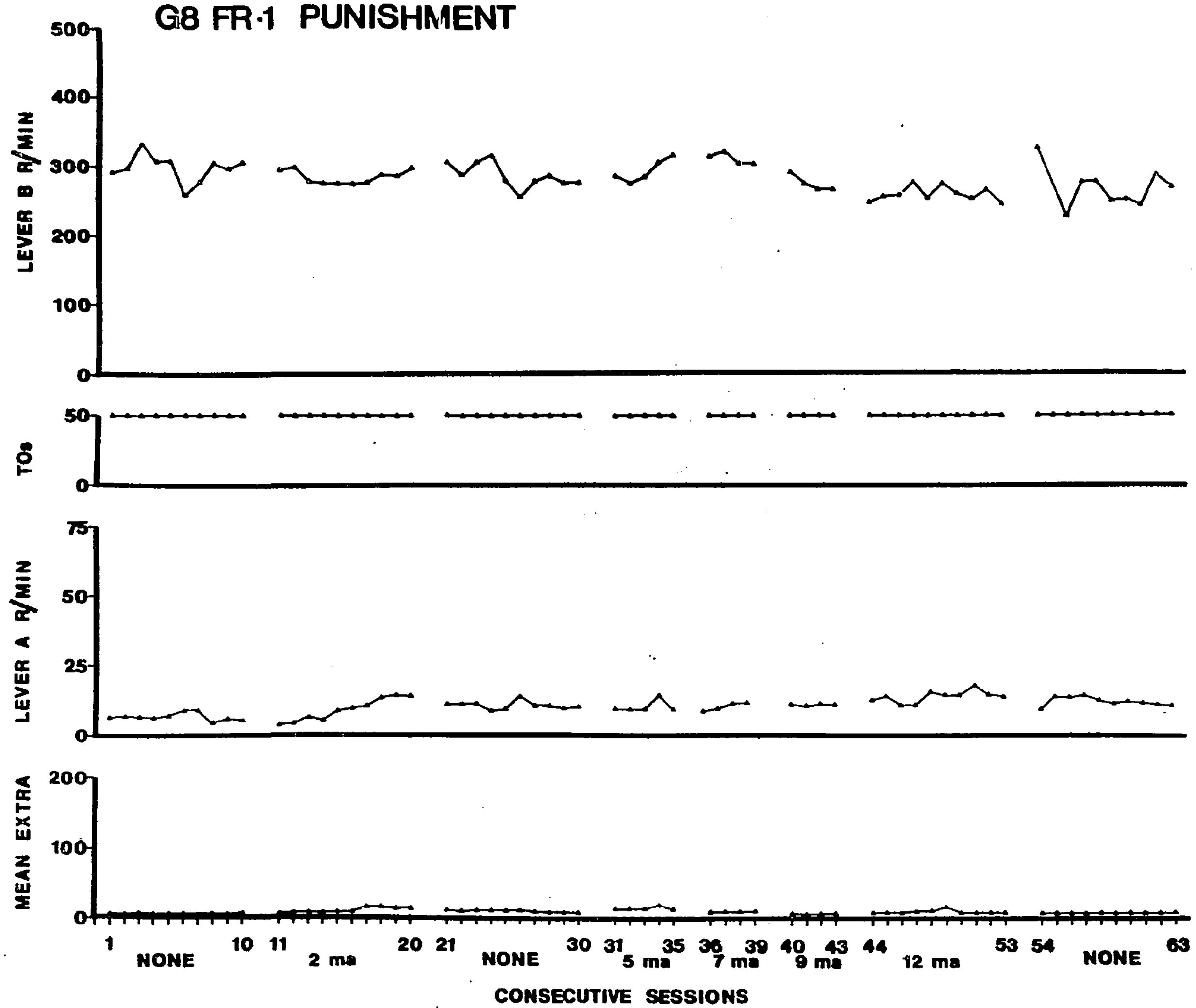
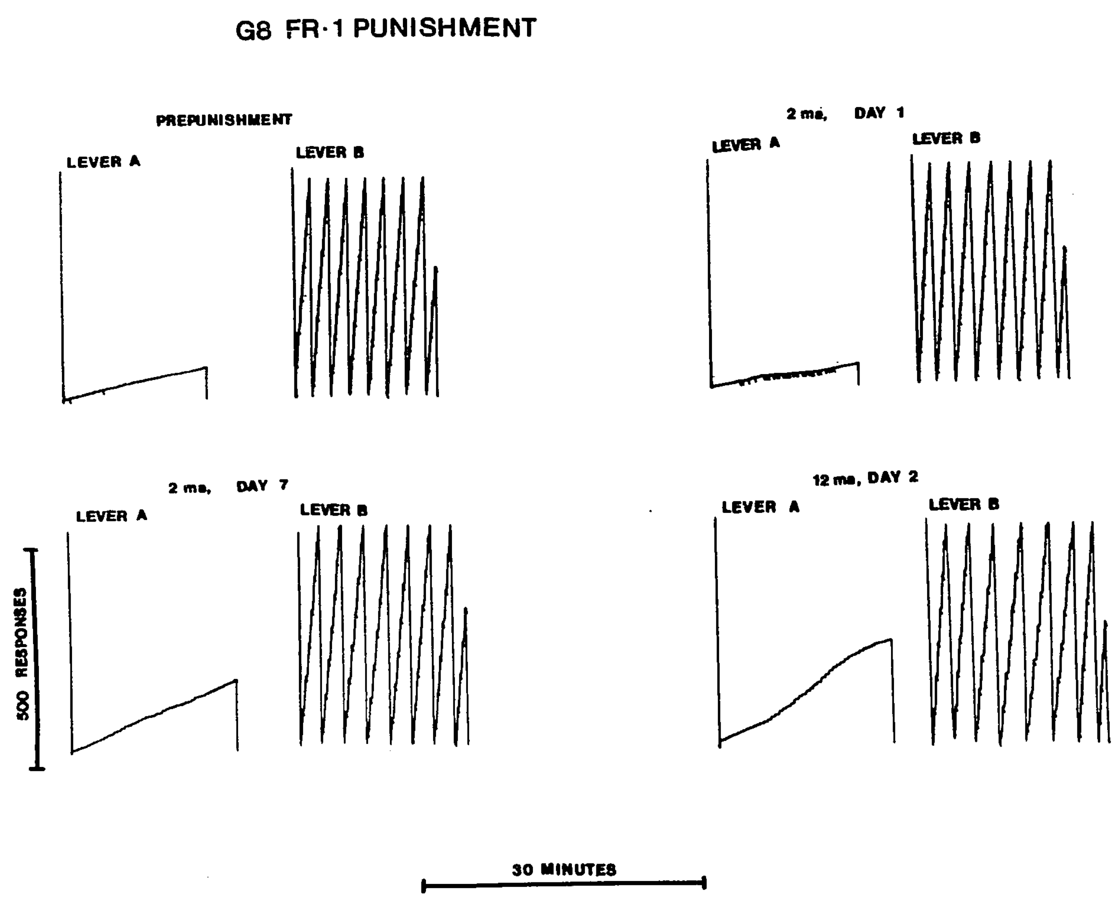


Fig. 12. Representative cumulative records are shown for G8 during FR-1 punishment. The upper left records are of prepunishment lever A and lever B performance. Upper right records show performance on lever A and lever B for the first day of 2 ma shock. Lower left records show performance on both levers for the seventh day of 2 ma shock, while lower right records show lever A and lever B performance for the second day of 12 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.


G8 FR·1 PUNISHMENT
PREPUNISHMENT
LEVER A
LEVER B
2 ms, DAY 1
LEVER A
LEVER B
2 ms, DAY 7
LEVER A
LEVER B
12 ms, DAY 2
LEVER A
LEVER B
500 RESPONSES
30 MINUTES

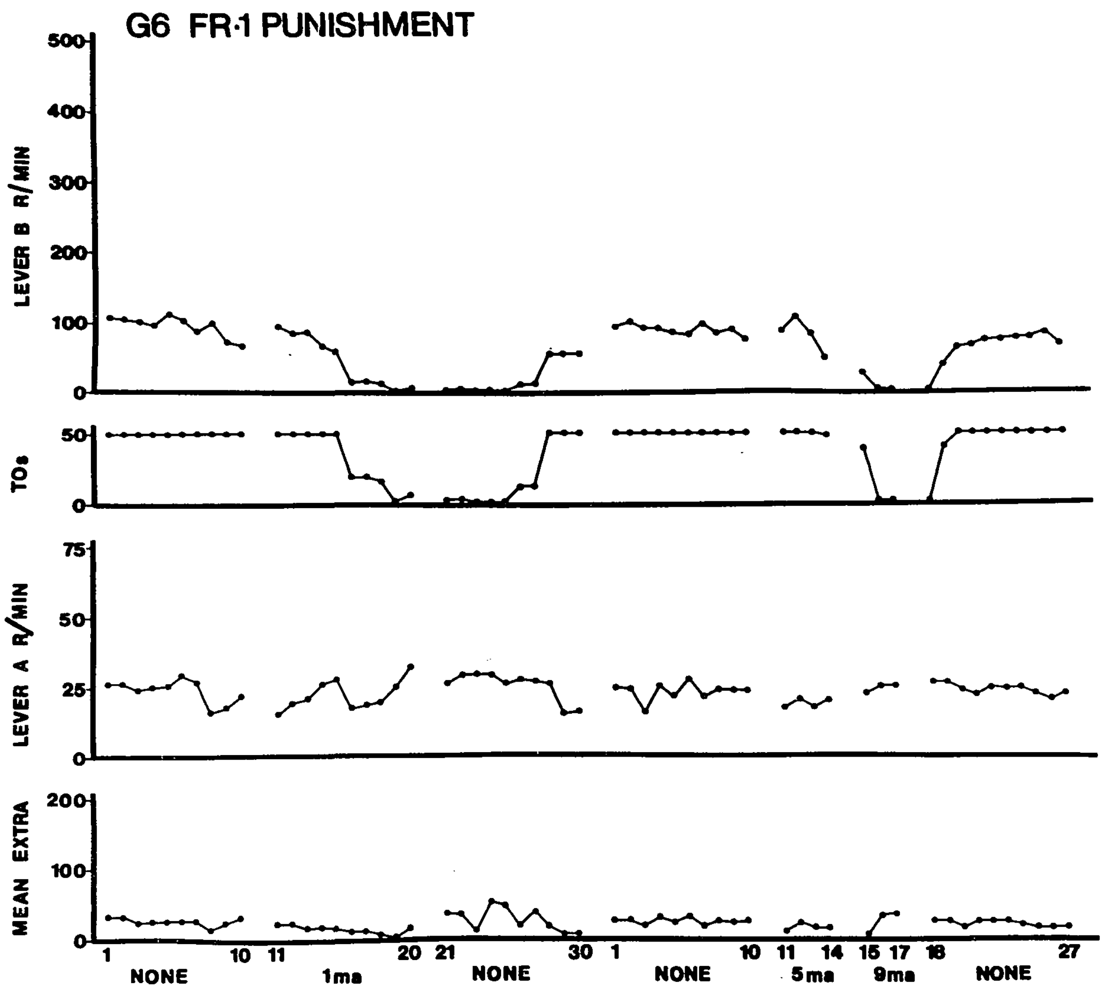
G6: FR-1 punishment was the third condition for G6 (figures 13 and 14). Again, a typical pattern of suppression under FR-1 punishment appeared. Long pauses occurred before the initiation of responding after a time out. Rate of responding on lever B, once it was initiated, was at a higher rate than before punishment. This animal was slightly atypical in that pauses occasionally occurred on lever B at points other than the time immediately following a time out (figure 14-1 ma, day 6). Since suppression was essentially complete under mild punishment, a record obtained under more intense punishment is not shown, and a record showing recovery following punishment is presented instead. Notice that as the animal was recovering, the pattern of responding which had developed under punishment was maintained. This maintenance of the typical punishment pattern after punishment was removed was frequently obtained for all punishment conditions. Due to space limitations recovery records usually are not shown.

FR-37 PUNISHMENT

Under FR-37 punishment the 37th effective response on lever B was punished for the 30 middle periods of active time. Two animals (G6 and G7) received FR-37 punishment as their first punishment condition.

G6: Figure 15 gives data for G6. A relatively small suppression of responding occurred on lever B under 1 ma shock. When punishment was removed behavior stabilized quickly at a slightly lower rate than before punishment. Performance on both lever A and lever B appeared more stable than it had been prior to punishment. Under 5 ma suppressive effects increased gradually until suppression was almost complete by day 6. The gradual decrease in lever B rate was accompanied by an increased rate on lever A and a marked increase in the number of ineffective responses which fell within the 2 second COD period (figure 15, mean extra). Under prepunishment conditions G6 had made

Fig. 13. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G6 for the FR-1 punishment condition. Each point represents a value for a single session. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 20), and following punishment (sessions 21 through 30). At this point stabilization procedures were put into effect. The next values are before punishment (sessions 1 through 10), during 5 ma shock (sessions 11 through 14), during 9 ma shock (sessions 15 through 17) and following punishment (sessions 18 through 27).



G6 FR-1 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1 10 11 20 21 30 1 10 11 14 15 17 18 27
NONE
1ma
NONE
NONE
5ma
9ma
NONE

Fig. _14_. Representative cumulative records are shown for G6 during FR-1 punishment. The upper record shows the prepunishment performance on lever B. The middle record shows lever B performance for the sixth day of 1 ma shock. Performance on lever B for the second day after punishment removal is shown in the lower record. Oblique downward deflections of the pen indicate periods of time out; paper drive was halted during each time out period.

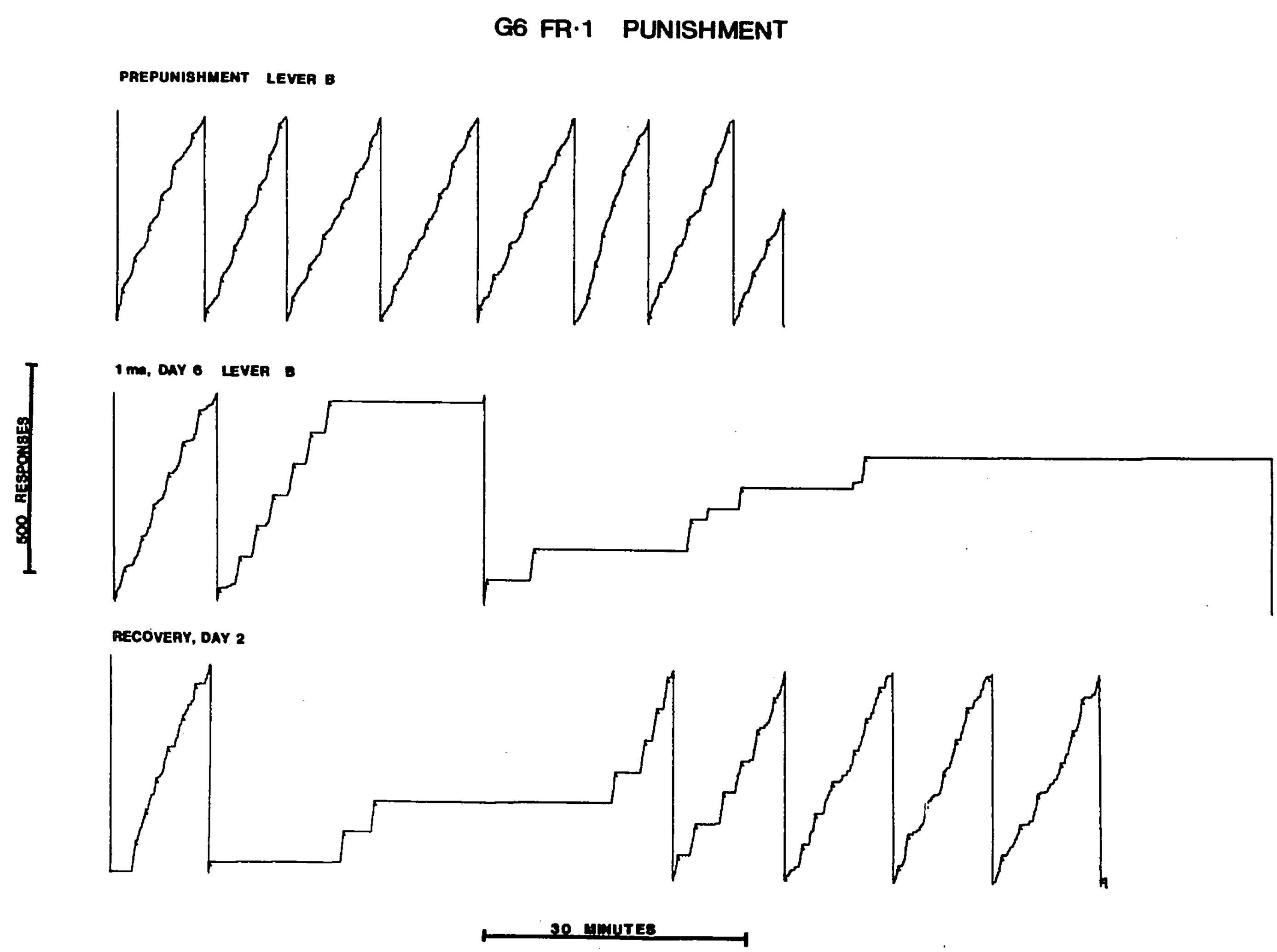
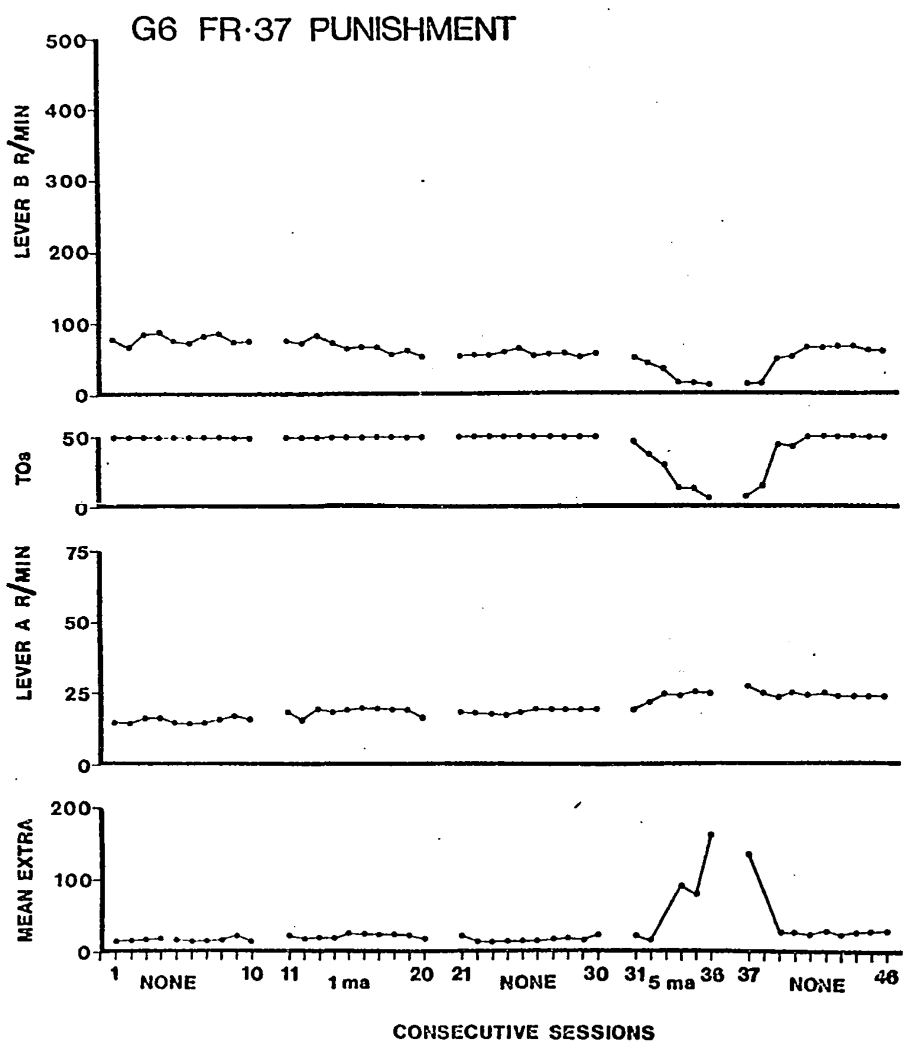

G6 FR·1 PUNISHMENT
PREPUNISHMENT LEVER B
1 ma, DAY 6 LEVER B
RECOVERY, DAY 2
500 RESPONSES
30 MINUTES

Fig. 15. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G6 for the FR-37 punishment condition. Each point represents a value for a single one of the 46 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 20), following punishment (sessions 21 through 30), during 5 ma shock (sessions 31 through 36), and again following punishment (sessions 37 through 46).


G6 FR·37 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1
NONE
10
11
1 ma
20
21
NONE
30
31
5 ma
36
37
NONE
46
CONSECUTIVE SESSIONS

relatively few ineffective or extra responses in spite of frequent switches from lever A to lever B. Typically, he paused briefly after responding on lever A before pressing lever B. This discrimination seems to have been lost under the 5 ma punishment. Since ineffective lever B responses were never punished this behavior may not be as unadaptive as it first appears. After punishment was removed, recovery occurred on lever B and the number of extra lever B responses dropped to a lower rate although somewhat greater than that prior to punishment.

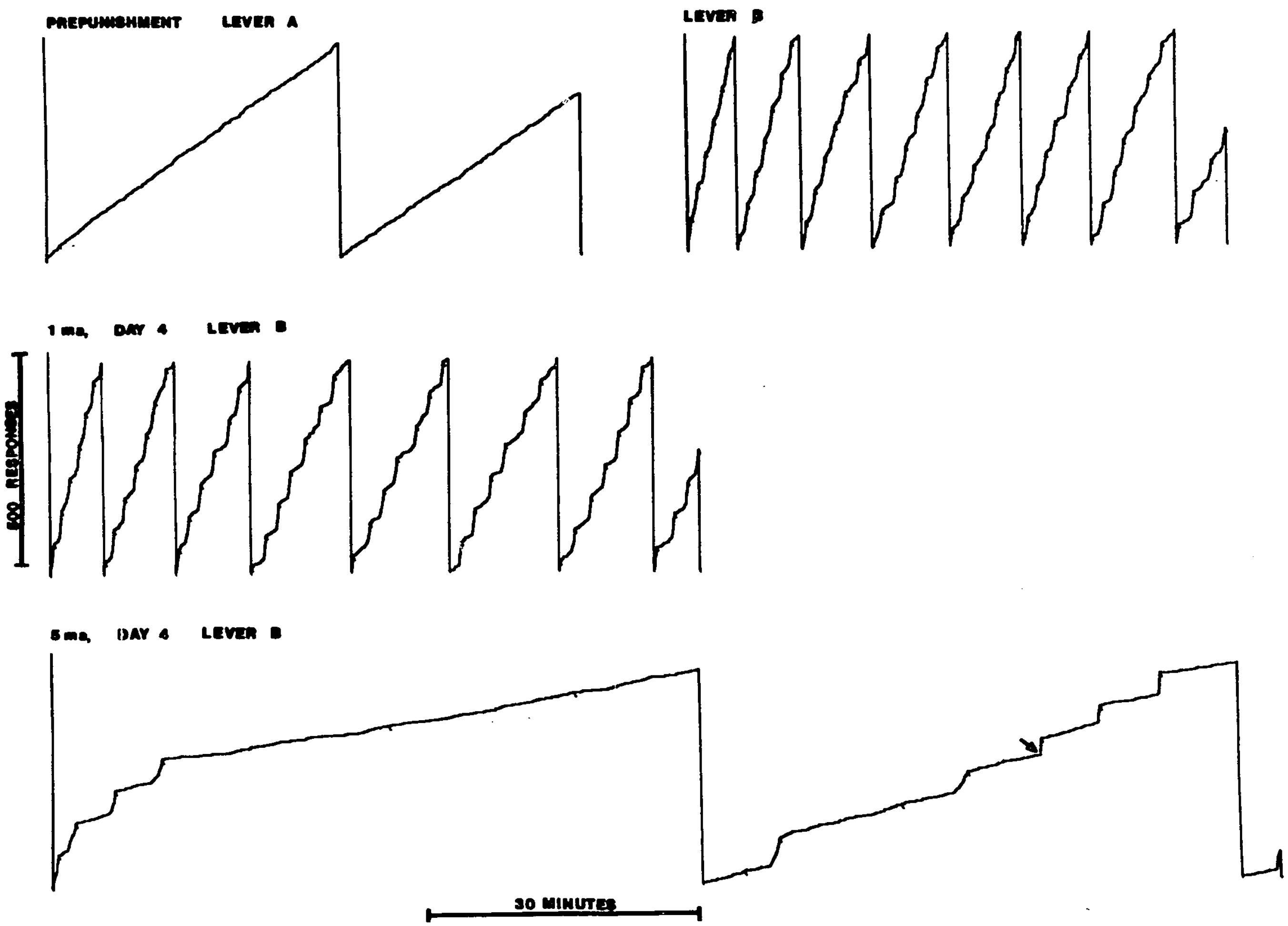
Sample cumulative records for G6 under FR-37 punishment are shown in figure 16. The prepunishment avoidance record shows a low, uniform rate. Bursts of responding on lever B increased in length toward the end of the ratio. By day 4 of 1 ma punishment, the rate of responding in the early part of the ratio was lower and more irregular. Responding in the last half increased in rate. By the 10th day breaks and irregularities during the first half of the ratios were even more pronounced. Once the shock for the middle response was delivered, this typically spurred a high and uninterrupted rate on lever B until the ratio requirement was completed. This high rate frequently began before shock. Restabilization occurred without further experimental manipulation but was at a lower rate than before the punishment condition.

Under 5 ma punishment (figure 16, day 4) only 14 time outs were earned. During the first 10 time outs a low rate throughout the ratio appeared on the lever B record. An arrow on the cumulative record marks the point during the eleventh period at which the first punishment shock was delivered. A low rate preceded the punishment shock, but the punishment shock initiated a high and uninterrupted rate of lever B responding. This occurred with each of the 4 time outs which were earned under punishment conditions.

By day 10 following punishment, recovery had occurred to the extent that the complete 50 time outs were earned during the session.

Fig. 16. Representative cumulative records are shown for G6 for the FR-37 punishment condition. The upper records are of prepunishment performance on lever A and lever B. The middle record shows performance on lever B for the fourth day of 1 ma shock. The lower record shows performance on lever B for the fourth day of 5 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

G6 FR-37 PUNISHMENT



However, rate was still considerably lower than it had been before punishment. Following every time out low rate responding on lever B occurred; responding in the last half of the ratio remained at a high rate.

G7: G7 also received FR-37 punishment as the first punishment condition. Figure 17 shows that punishment with 1 ma or 2 ma shock had little suppressive effects. Five ma shock led to moderate suppression. As lever B rate was being suppressed, the rate on lever A and the number of ineffective (extra) lever B responses increased. Under more intense (9 ma) punishment the increase in lever A responses and number of extra responses was even more marked. After suppression was nearly complete, under 12 ma punishment, rate on lever A and the number of extra responses again decreased.

Typical cumulative records can be seen in figure 18. The prepunishment lever B record was characterized by a high rate of responding usually uninterrupted. One or two avoidance responses typically preceded this rapid responding on lever B.

Little change occurred in the records when punishment shock was 1 or 2 ma. When shock was increased to 5 ma, slight breaks began appearing in the early half of the ratios on the lever B records. The avoidance (lever A) record developed a smoother appearance since lever A responses occurred during these breaks in lever B responding.

Following 5 ma punishment the appearance of the record changed fairly rapidly to the prepunishment pattern. By day 9 the avoidance record was again characterized by a few responses at the beginning of the period followed by a brief pause while the 75 lever B responses were being run off.

On the first day of punishment with 9 ma shock, avoidance rate increased during the middle 30 time out sections. The FR record clearly showed rough grain and breaks during the first half of the ratio for the middle part of the session. Responding remained

Fig. 17. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G7 during the FR-37 punishment condition. Each point represents a value for a single session. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 14), during 2 ma shock (sessions 15 through 18), during 5 ma shock (sessions 19 through 28), and following punishment (sessions 29 through 38). Stabilization procedures intervened before punishment under more severe shock. The next values are before punishment (sessions 1 through 10), during 9 ma shock (sessions 11 through 14), during 12 ma shock (sessions 15 through 24), and following punishment (sessions 25 through 34).

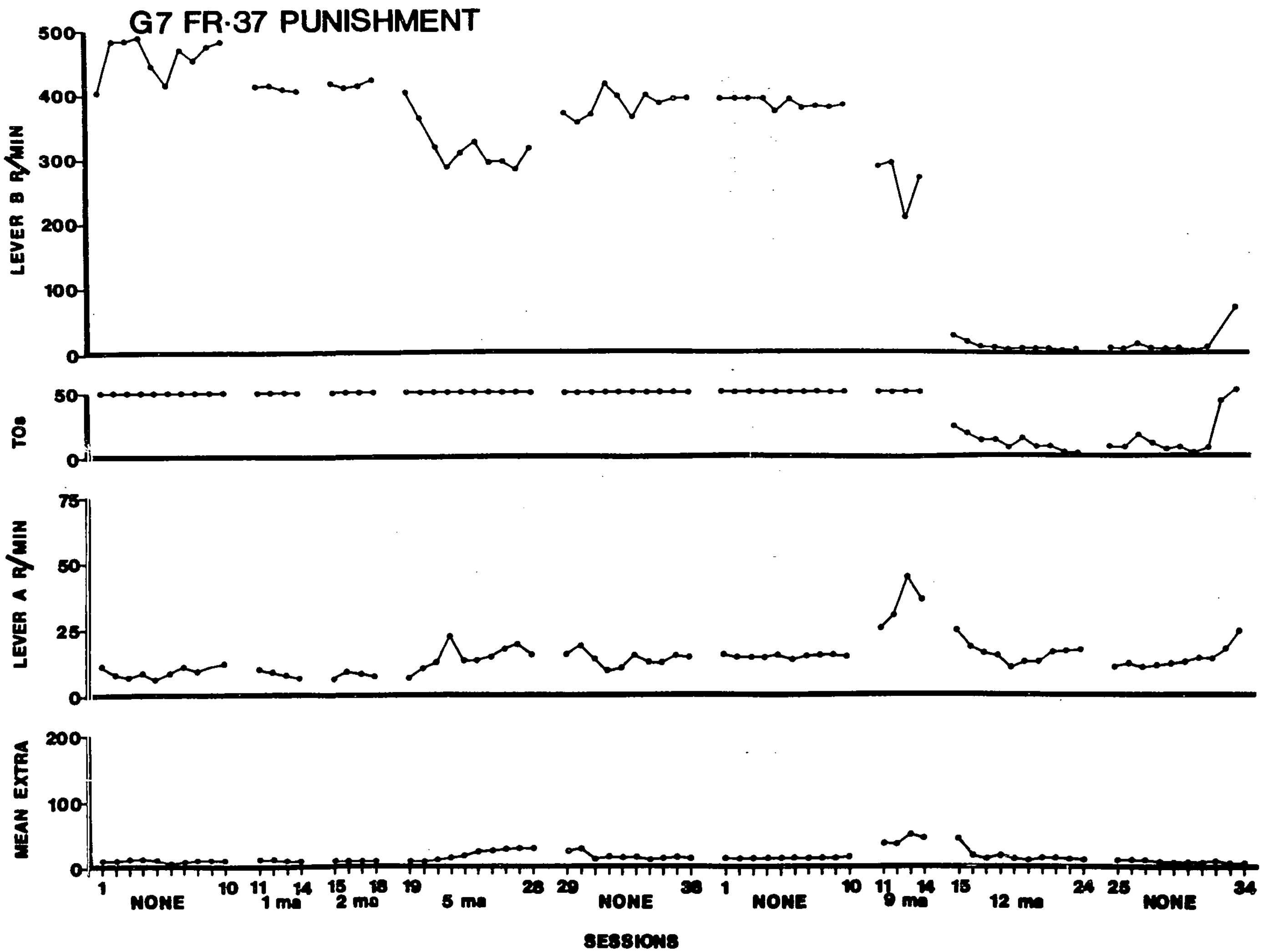
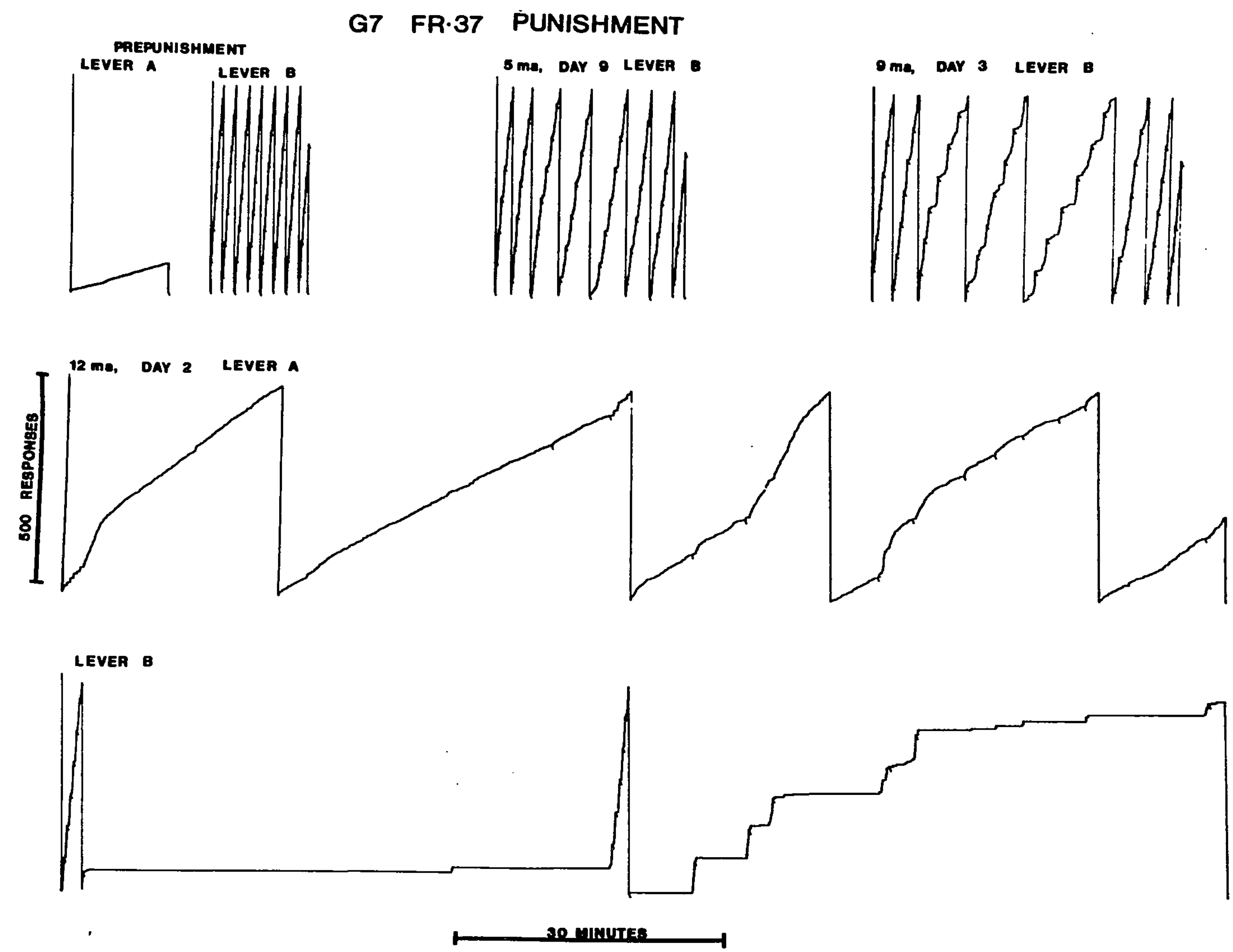

G7 FR·37 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1
NONE
10
11
1 ma
14
15
2 ma
18
19
5 ma
28
29
NONE
38
1
NONE
10
11
9 ma
14
15
12 ma
24
25
NONE
34
SESSIONS

Fig. 18. Representative cumulative records are shown for G7 during the FR-37 punishment condition. In the upper row, records are shown of performance on lever A and lever B before punishment, performance on lever B for the ninth day of 5 ma shock, and performance on lever B for the third day of 9 ma shock. The middle record shows responding on lever A and the lower record responding on lever B for the second day under 12 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.


G7 FR·37 PUNISHMENT
PREPUNISHMENT
LEVER A
LEVER B
5 ms, DAY 9 LEVER B
9 ms, DAY 3 LEVER B
12 ms, DAY 2 LEVER A
500 RESPONSES
LEVER B
30 MINUTES

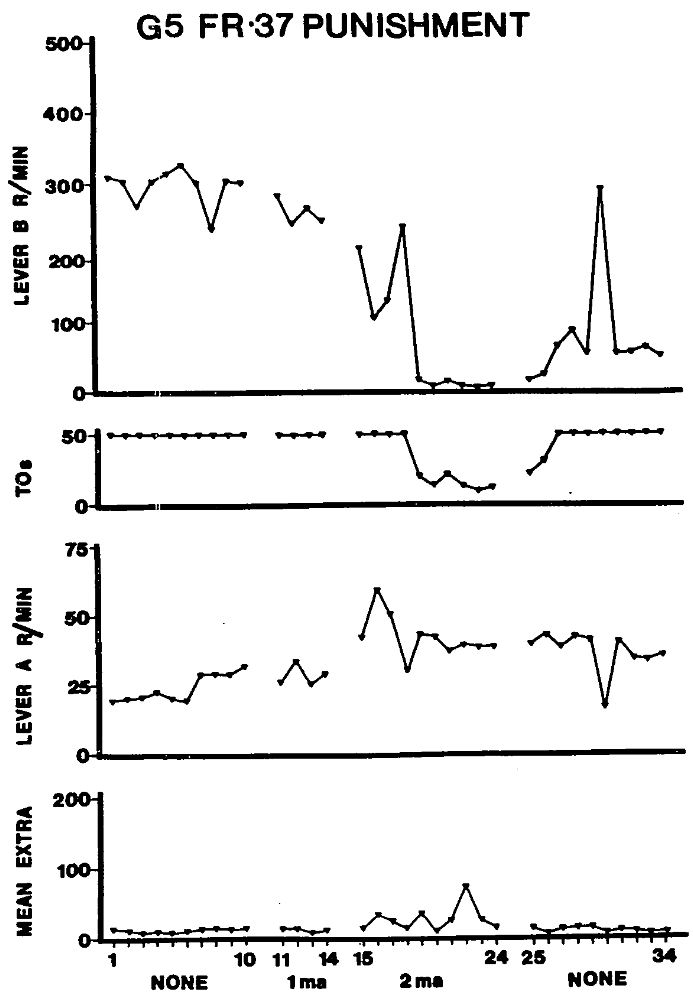
rapid during the last half. By the 3rd day this change in pattern was more marked (figure 18-9ma, day 3). Disruptions on the FR record coincided with runs of responses on lever A. Rapid undisrupted lever B rates occurred at the beginning and end of the session. These were not confined to the 10 unpunished periods occurring at the beginning and end of the session since in both cases the more rapid rate extended into the punished middle 30 time outs.

Under 12 ma punishment, long pauses were occurring on lever B by day 2 (figure 18). These pauses typically occurred after responding had been initiated and rarely occurred immediately after the time out as was the case for FR-1 punishment. Sometimes a burst of responses would be followed by a pause, another burst, and then another pause. As before, disruptions were much fewer and pauses seldom occurred during the last half of the ratio. Heightening of rate following punishment shock was obscured in this animal because of the high prepunishment rate. This pattern is consistent with that obtained for other animals under FR-37 punishment since breaks and disruptions were mainly confined to the first half of the ratio.

In the 10 days after punishment was discontinued little recovery occurred.

G5: Data for G5 under FR-37 punishment are shown in figure 19. This was the third punishment condition for G5. Again, suppression on lever B was accompanied by marked increases on lever A and in the number of ineffective lever B responses. Suppression was almost complete under 2 ma punishment. Only a moderate amount of recovery occurred after punishment was removed and lever A rate remained high except for one session during which lever B rate rose sharply and lever A rate dropped sharply. Since recovery was not complete, restabilization procedures were begun. An equipment failure caused the animal to receive several hundred unavoidable shocks. This animal subsequently died and data are not available for punishment at

Fig. 19. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G5 during the FR-37 punishment condition. Each point represents a value for a single one of the 34 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 14), 2 ma shock (sessions 15 through 24), and following punishment (sessions 25 through 34).


G5 FR·37 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1
10
11
14
15
24
25
34
NONE
1 ma
2 ma
NONE

additional shock intensities for FR-37.

Figure 20 shows representative cumulative records obtained under 1 ma and 2 ma punishment. Note that the prepunishment stabilized performance on lever B is at a higher rate than that obtained before the first punishment condition (shown in figure 8). G5 was originally one of the animals with a relatively low lever B rate. The initial effects of FR-37 punishment were a heightening of lever A rate and an increase in the number of small breaks during the first half of the ratio on lever B (figure 20-1 ma, day 2). These effects were more pronounced under punishment at 2 ma. The lever B record for day 2 shows prolonged low rates occurring early in the ratio during the middle part of the session. By day 4 results similar to those obtained for G6 appeared. Frequently a low rate was sustained until the punishment shock occurred. The shock then initiated rapid responding on lever B which was sustained until the time out was earned. Sometimes the high rate was begun before the shock and continued until the 75 responses were completed. On the original records it was possible to determine where the punishment shock occurred in these cases, because the shock caused a body jerk which disrupted responding. This was observed for all animals and probably accounts for the small disruptions in performance noted by Dardano and Sauerbrunn (1964) at the point of delivery of FR-37 punishment shock.

A marked increase in rate on lever A appeared after punishment (compare prepunishment lever A record with record for day 2, 2 ma shock in figure 20).

G8: Figure 21 summarizes G8's performance under FR-37 punishment. This was the last punishment condition for G8, and was the only one of the three conditions which produced suppression. Little suppression occurred until punishment shock level was increased to 12 ma. At this intensity suppression occurred abruptly and no recovery took place when punishment was removed. Suppression was accompanied by large

Fig. 20. Representative cumulative records are shown for G5 during the FR-37 punishment condition. In the upper row, performance is shown on lever A and lever B before punishment, and performance on lever A and lever B is shown for the second day under 1 ma shock. The middle records are of responding on lever A and lever B for the second day of 2 ma shock. The bottom record is of performance on the fourth day of 2 ma shock. Oblique downwards deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

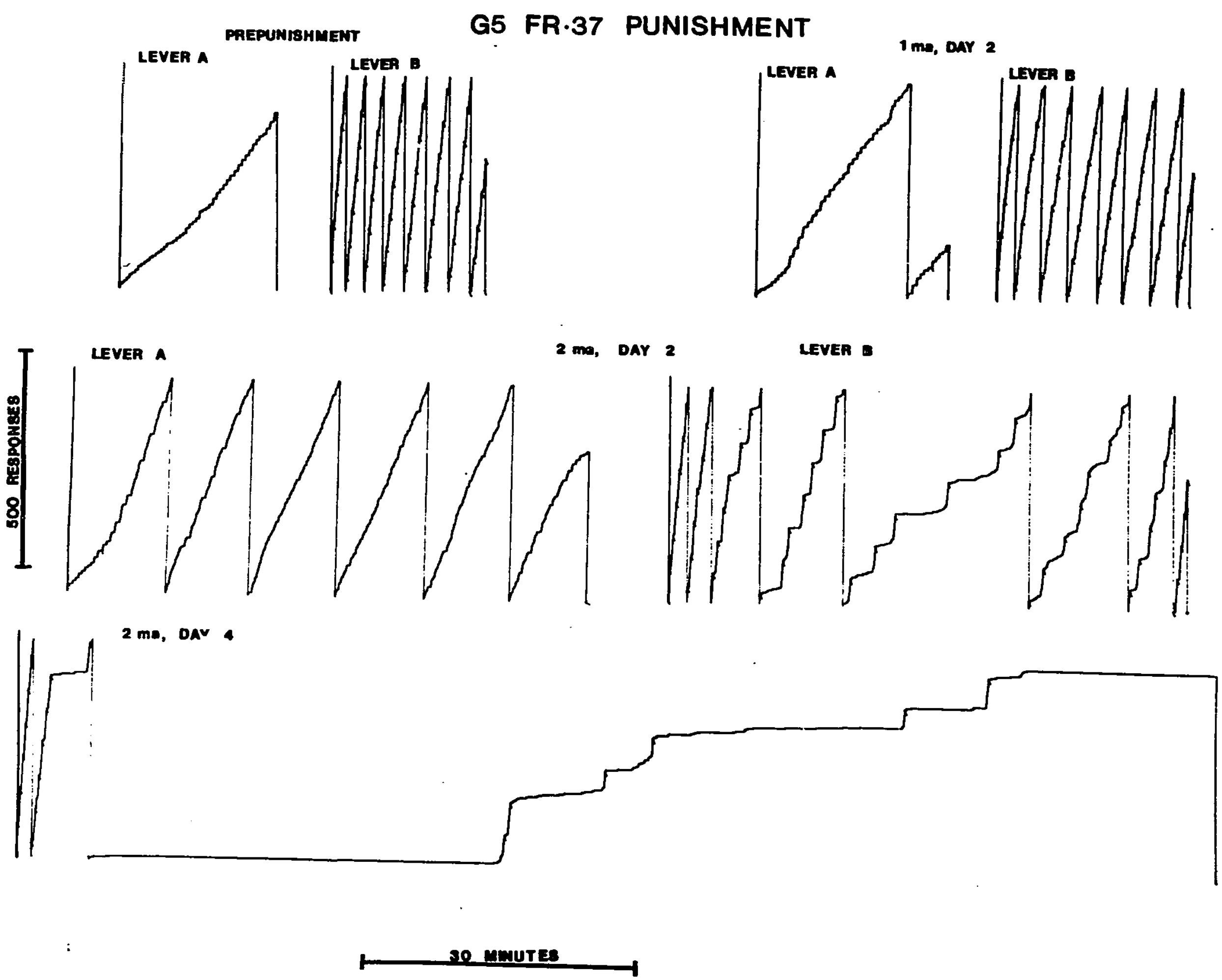
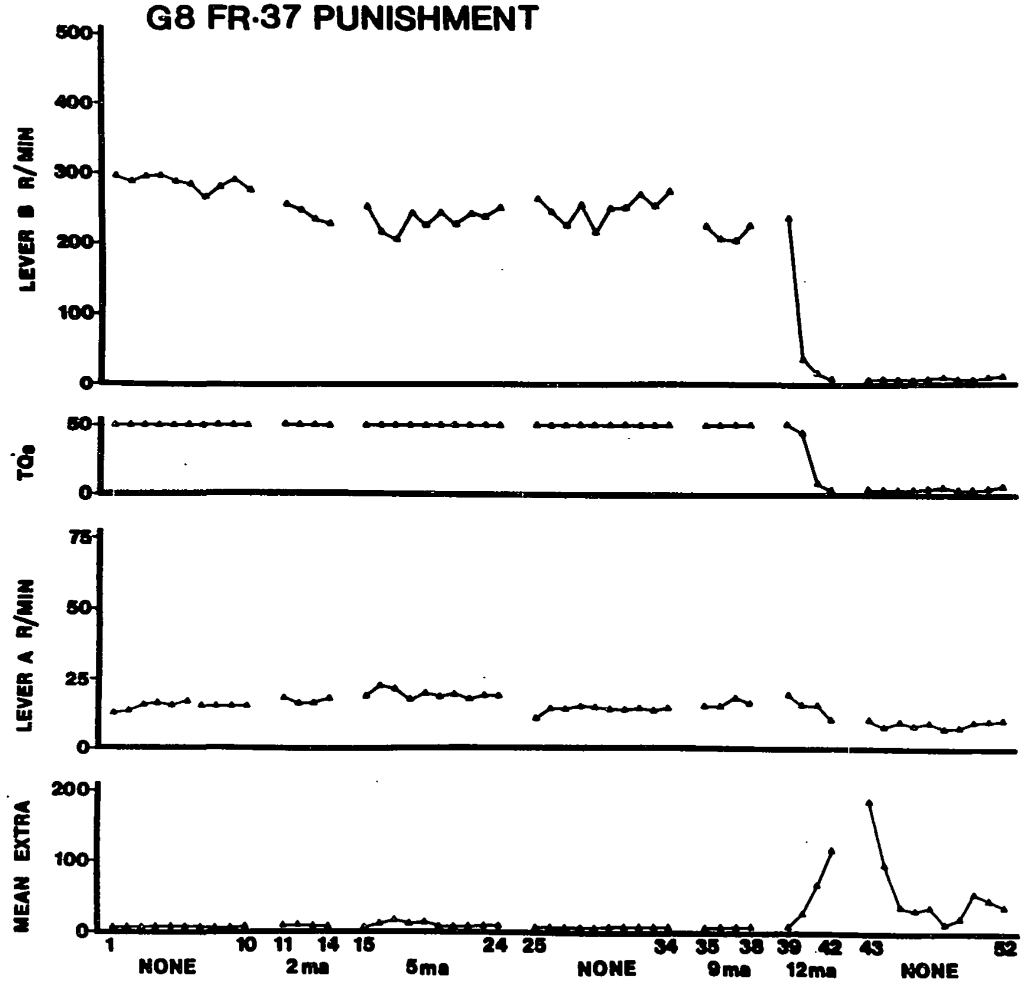

G5 FR·37 PUNISHMENT
PREPUNISHMENT
LEVER A
LEVER B
1 ma, DAY 2
LEVER A
LEVER B
500 RESPONSES
LEVER A
2 ma, DAY 2
LEVER B
2 ma, DAY 4
30 MINUTES

Fig. 21. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and average number of extra responses per time out are plotted for G8 during the FR-37 punishment condition. Each point represents a value for a single one of the 52 consecutive sessions. Values for each measure are given before punishment (sessions 1 to 10), during 2 ma shock (sessions 11 through 14), during 5 ma shock (sessions 15 to 24), following punishment (sessions 25 through 34), during 9 ma shock (sessions 35 through 38), during 12 ma shock (sessions 39 through 42), and following punishment (sessions 43 through 52).

G8 FR·37 PUNISHMENT



increases in the number of extra responses on lever B, but did not lead to a heightened rate on lever A.

As Figure 22 reveals, the initial effect of punishment was to increase small breaks during the first half of the ratios for the middle part of the session. Under 12 ma shock, marked suppression occurred. The record shown for day 2 reveals the pattern typical of FR-37 punishment. For two of the four time outs which were earned after suppression had begun, a very low rate occurred until the punishment shock was delivered. The shock then spurred an uninterrupted rapid rate which continued until the time out was earned. Although FR-37 punishment led to disruption throughout the first half of the ratio, the disruption was greatest immediately following a time out. The post-TO pauses typical of FR-1 punishment did not appear; the pauses were replaced by a low rate with FR-37 punishment.

FR-75 PUNISHMENT

G8: Data and cumulative records for G8 under FR-75 punishment are shown in figures 23 and 24. This was the first punishment condition for G8. Only a relatively small amount of suppression on lever B occurred even under punishment shock of 12 ma. Some increases in the number of extra responses on lever B and in lever A rate accompanied the mild suppression. An increase in number of shocks from inefficient avoidance responding on lever A also occurred. This increase in shocks on the avoidance program was also found for FR-1 punishment (described earlier). It is interesting to note in figure 24 that shocks occurred on the avoidance record predominantly at the beginning or at the end during the unpunished parts of the session.

Under punishment of 12 ma small breaks occurred throughout the ratio although most occurred near the beginning of the active time period. The only marked suppression effect that appeared throughout the FR-75 punishment series occurred on day 9 of 12 ma punishment. For one period of active time (figure 24-12 ma, day 9) a low lever B

Fig. 22. Representative cumulative records are shown for G8 during the FR-37 punishment condition. In the upper row, performance is shown on lever A and lever B performance on the fifth day of 5 ma shock. The middle row shows records of performance for lever A and lever B on the third day of 9 ma shock. At the bottom a record of lever B responding on the second day of 12 ma shock is given. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

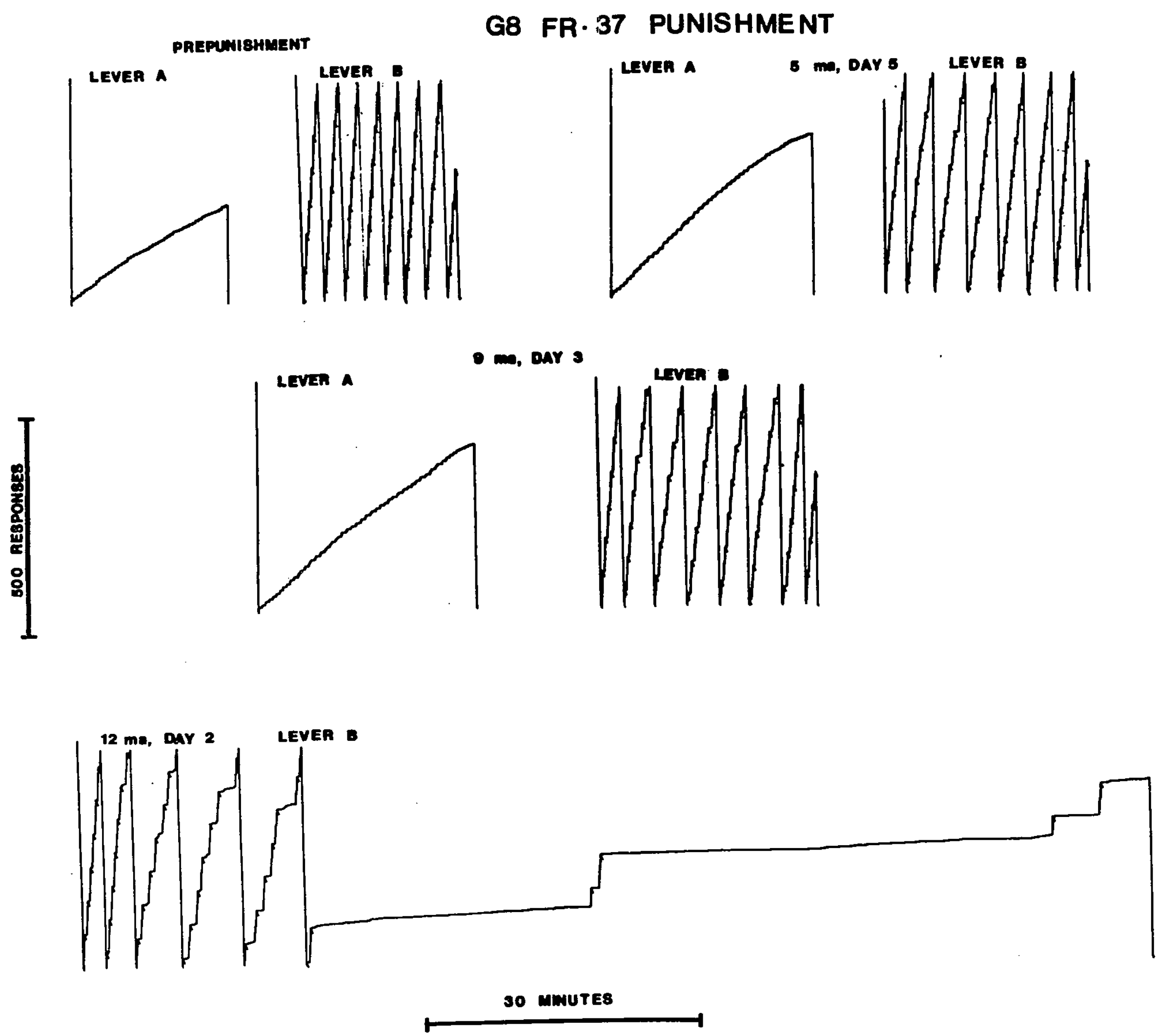

G8 FR·37 PUNISHMENT
PREPUNISHMENT
LEVER A
LEVER B
LEVER A
5 ms, DAY 5
LEVER B
9 ms, DAY 3
LEVER A
LEVER B
500 RESPONSES
12 ms, DAY 2
LEVER B
30 MINUTES

Fig. 23. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are potted for G8 during the FR-75 punishment condition. Each point represents a value for a single one of the 66 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 20), following punishment (sessions 21 through 30), during 5 ma shock (sessions 31 through 34), 7 ma shock (sessions 35 through 38), 9 ma shock 9sessions 39 through 42), 11 ma shock (sessions 43 through 46), 12 ma shock (sessions 47 through 56, and following punishment (sessions 57 through 66).

G8 FR·75 PUNISHMENT

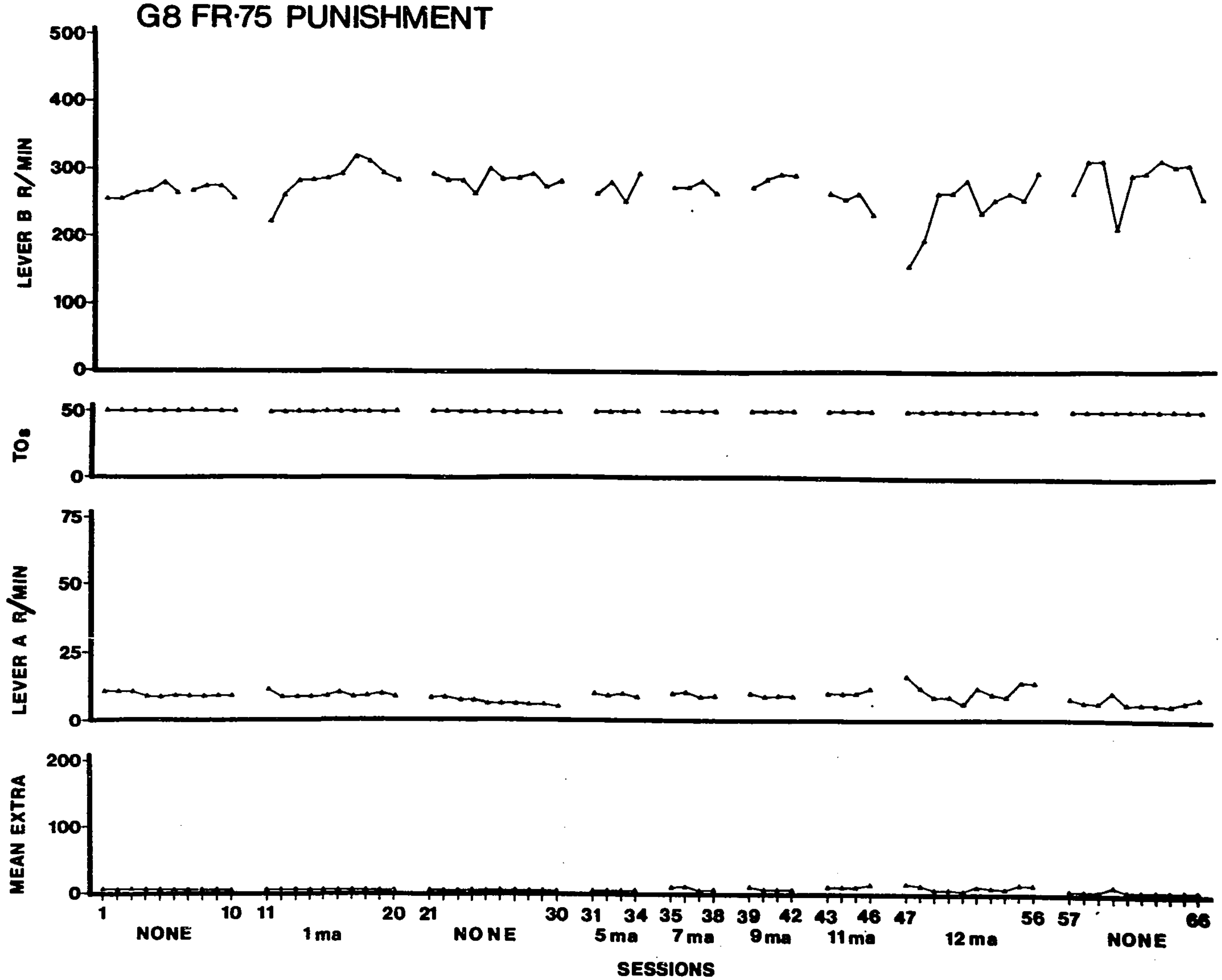
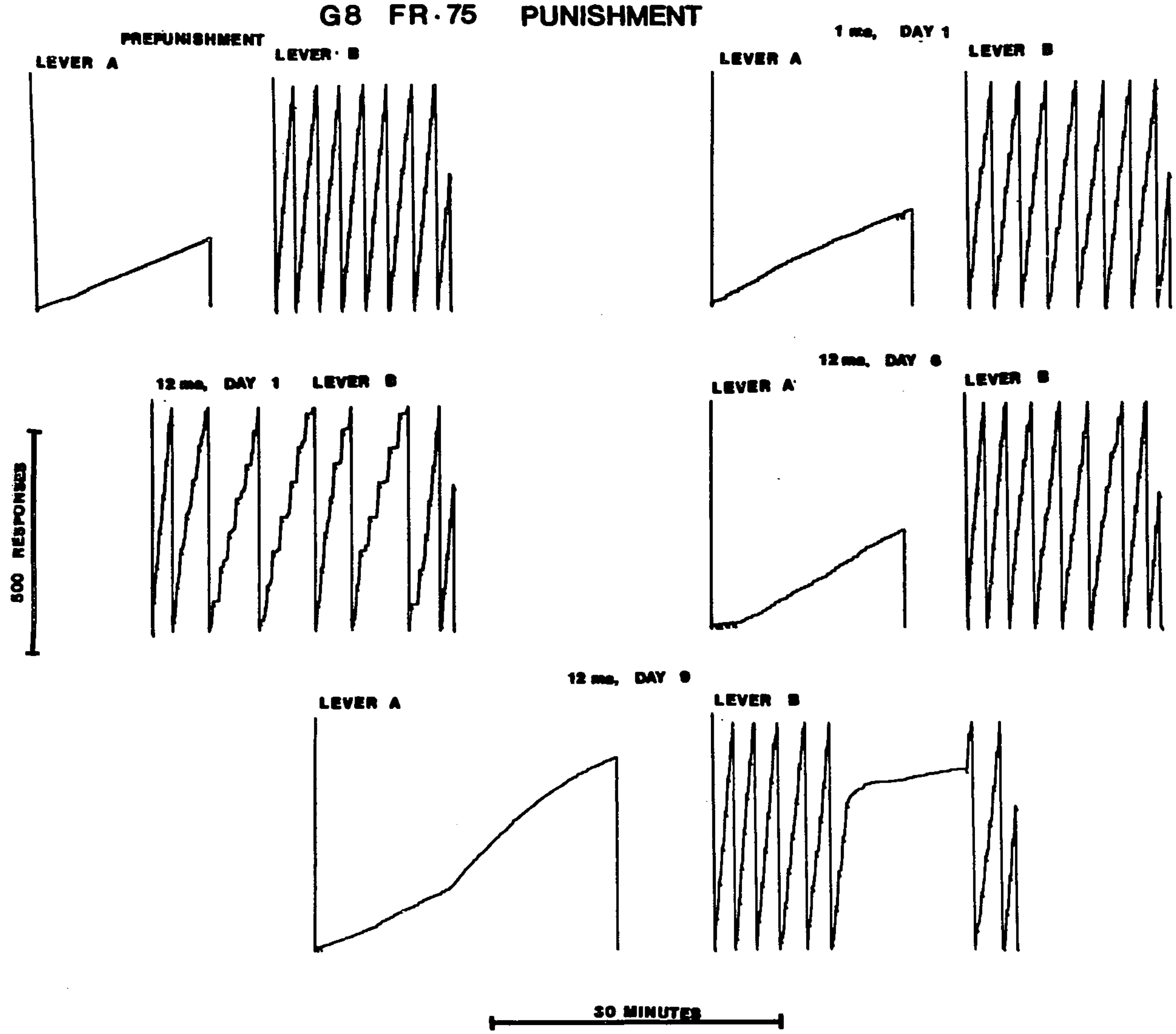


Fig. 24. Representative cumulative records are shown for G8 during the FR-75 punishment condition. In the upper row pre-punishment performance is shown on lever A and lever B, and records of responding on both levers are shown for the first day of 1 ma shock. The middle row shows performance on both levers for the sixth day of 12 ma shock. In the bottom row performance is shown on lever A and lever B for the ninth day of 12 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

G8 FR·75 PUNISHMENT

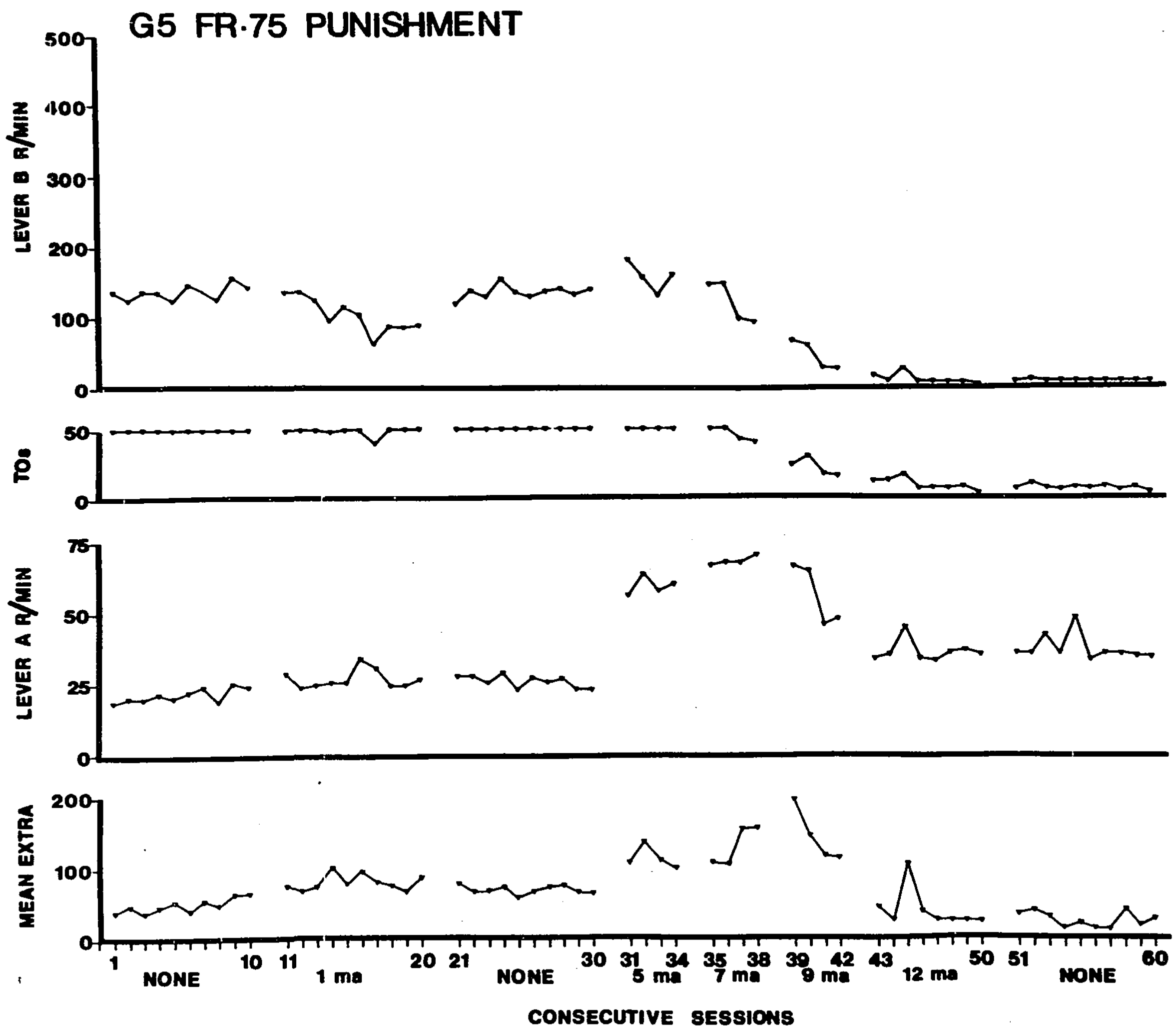


rate continued throughout the period. This is a typical FR-75 punishment effect found with other animals. The suppression on lever B was accompanied by an increase in lever A responding. This was, however, an atypical effect for G8 since it was the only occasion on which marked suppression occurred.

G5: FR 75 punishment was the second condition for G5. Performance measures and representative cumulative records are shown for G5 in figures 25 and 26. A moderate amount of suppression on lever B occurred with a shock intensity of 1 ma. This was accompanied by an increased rate on lever A and an increased number of ineffective responses on lever B. Recovery occurred upon removal of punishment and no restabilization procedures were necessary. Under punishment with 5 ma, 7 ma, and 9 ma the increased rate on lever A and the number of extra responses on lever B more than doubled (figure 25). These decreased again with more complete suppression under 12 ma shock.

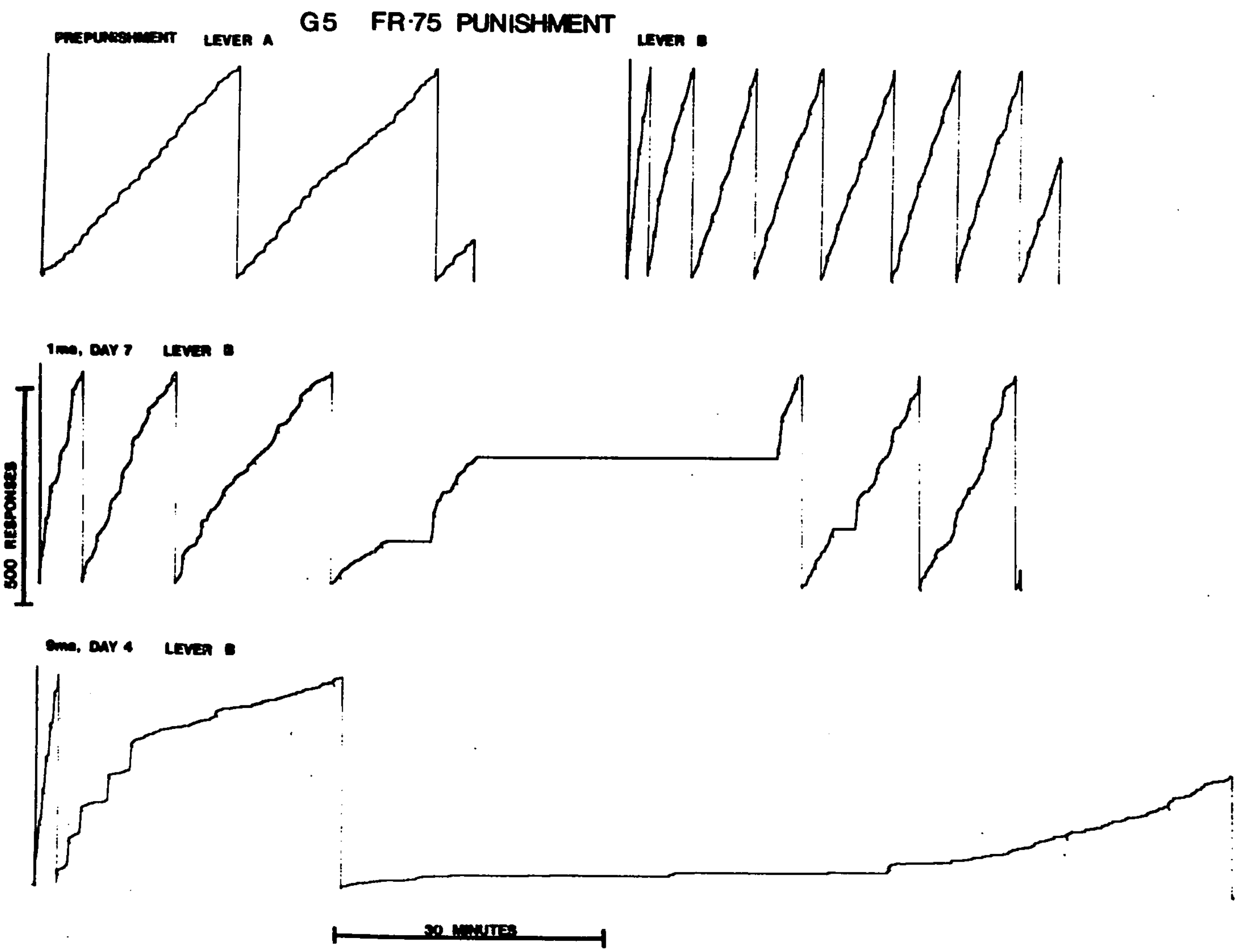
Figure 26 shows cumulative records for G5. Before punishment, lever B performance was stable, with the usual lower rates at the beginning of the period and longer bursts of responses near the completion of the ratio. Responding on lever A showed marked decelerations of rate within each period of active time. Under 1 ma punishment this smooth deceleration became less well defined or absent. Lever B rate was highest during the first 8 or 10 ratios. During these periods the characteristics of performance noted during sessions preceeding punishment were still apparent. After punishment began on the 11th time out, the appearance of the record changed. More variability developed. Rather than the accelerated performance formerly obtained, with the longest runs occurring near the end of the active time period, breaks and changes in rate on lever B appeared throughout ratios. Occasionally accelerations and decelerations alternated, giving an S-shaped appearance to the lever B record. Sometimes bursts of responding appeared in the middle of the period rather than at the

Fig. _25_. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G5 during the FR-75 punishment condition. Each point represents a value for a single one of the 60 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 20), following punishment (sessions 21 through 30), during 5 ma shock (sessions 31 through 34), 7 ma shock (sessions 35 through 38), 9 ma shock (sessions 39 through 42), 12 ma shock (sessions 43 through 50), and following punishment (sessions 51 through 60).



G5 FR·75 PUNISHMENT
LEVER B R/MIN
500
400
300
200
100
0
TOs
50
0
LEVER A R/MIN
75
50
25
0
MEAN EXTRA
200
100
0
1
NONE
10
11
1 ma
20
21
NONE
30
31
34
5 ma
35
38
7 ma
39
42
9 ma
43
12 ma
50
51
NONE
60
CONSECUTIVE SESSIONS

Fig. 26. Representative cumulative records are shown for G5 during the FR-75 punishment condition. In the upper row, lever A and lever B performance before punishment is shown. In the middle row lever B responding during the seventh day of 1 ma shock is given. The lower row shows a record of lever B performance on the fourth day of 9 ma shock. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.


G5 FR·75 PUNISHMENT
PREPUNISHMENT LEVER A
LEVER B
1ma, DAY 7 LEVER B
500 RESPONSES
9ma, DAY 4 LEVER B
30 MINUTES

end. The most characteristic feature was the lack of emergence of any clear pattern; breaks and changes occurred throughout the ratios with no consistent change in pattern as the FR requirement neared completion.

By day 7 (figure 26-1ma) avoidance rate was a little lower. Performance was effective on lever A, since no avoidance shocks were delivered, but not efficient, since a much higher rate was sustained than necessary to avoid shock. No consistent pattern was apparent.

On lever B, the characteristics of the record for day 4 were still apparent but with a new feature emerging. Breaks in the record with no FR responding occurred. Two relatively short breaks occurred after a few lever B responses had been made; another long break occurred near the completion of an FR requirement.

After punishment was discontinued recovery was rapid. By day 2 deceleration during periods of active time was again apparent on the avoidance record.

Similar patterns emerged under punishment of 5 ma, 7 ma, 9 ma and 12 ma. On lever B, responding sometimes showed breaks and rough grain throughout a period and sometimes was rough only at the beginning of the period with runs of responses preceding a time out. The breaks in responding were never right after a time out, as occurred with stabilized unpunished performance for some animals (post-reinforcement pausing) or under FR-1 punishment. As the shock intensity increased the final characteristics of FR 75 punishment emerged. A rough undifferentiated grain occurred throughout the ratios after punishment began. This is apparent in figure 26-9ma, day 4. Immediately following the onset of punishment of the 75th response during the 11th TO, an undifferentiated, low rate with rough grain emerged and continued throughout the rest of the session.

After punishment was removed, recovery did not take place. By day 6, five time outs were earned at a rapid rate (at a higher rate than for previous prepunishment performance) followed by a complete cessation of responding on lever B. A few lever B responses as well as a burst of responses on lever A followed the sole shock which the animal failed to avoid.

<u>G6</u>: A similar pattern of suppression was obtained for G6. An examination of figure 27 shows the same marked increase in the rate of lever A responding and in the number of ineffective responses as suppression on lever B developed. Figure 28 shows representative cumulative records.

The prepunishment lever B performance was one of low initial rate during periods of active time. This was a feature which emerged with FR-37 punishment and was not eliminated by stabilization procedures between conditions.

Under 1 ma punishment low rates with rough grain sometimes continued throughout the period of active time for lever B. This occurred during the middle part of the record, with some recovery of a pattern similar to the prepunishment one near the end of the session. This increase in rate occurred even though punishment was still being received for the 75th response since fewer than 40 TO's were earned during the session.

Following punishment (1 ma) recovery did not occur to the extent that 50 TO's were earned during the 2½ hour session. However, the pattern of undifferentiated irregular responding throughout the ratio largely disappeared and was replaced by the former pattern of an initial low rate followed by runs until the ratio was completed. The initial low rate remained lengthy relative to prepunishment performance.

Restabilization procedures were used before punishment with 5 ma shock. Under punishment of 5 ma, the undifferentiated low rate throughout the ratio emerged immediately following the 11th TO (the first punished one) and continued throughout the session with only one additional ratio being completed in the session. An arrow marks the point at which the first punishment shock was delivered in

Fig. 27. In these graphs lever B responses per minute, number of timeouts earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G6 during the FR-75 punishment condition. Each point represents a value for a single session. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 20), and following punishment (sessions 21 through 30). Stabilization procedures intervened before punishment under more severe shock. The next values are before punishment (sessions 1 through 10), during 5 ma shock (sessions 11 through 14), 9 ma shock (sessions 15 through 24), and following punishment (sessions 25 through 34).

G6 FR·75 PUNISHMENT

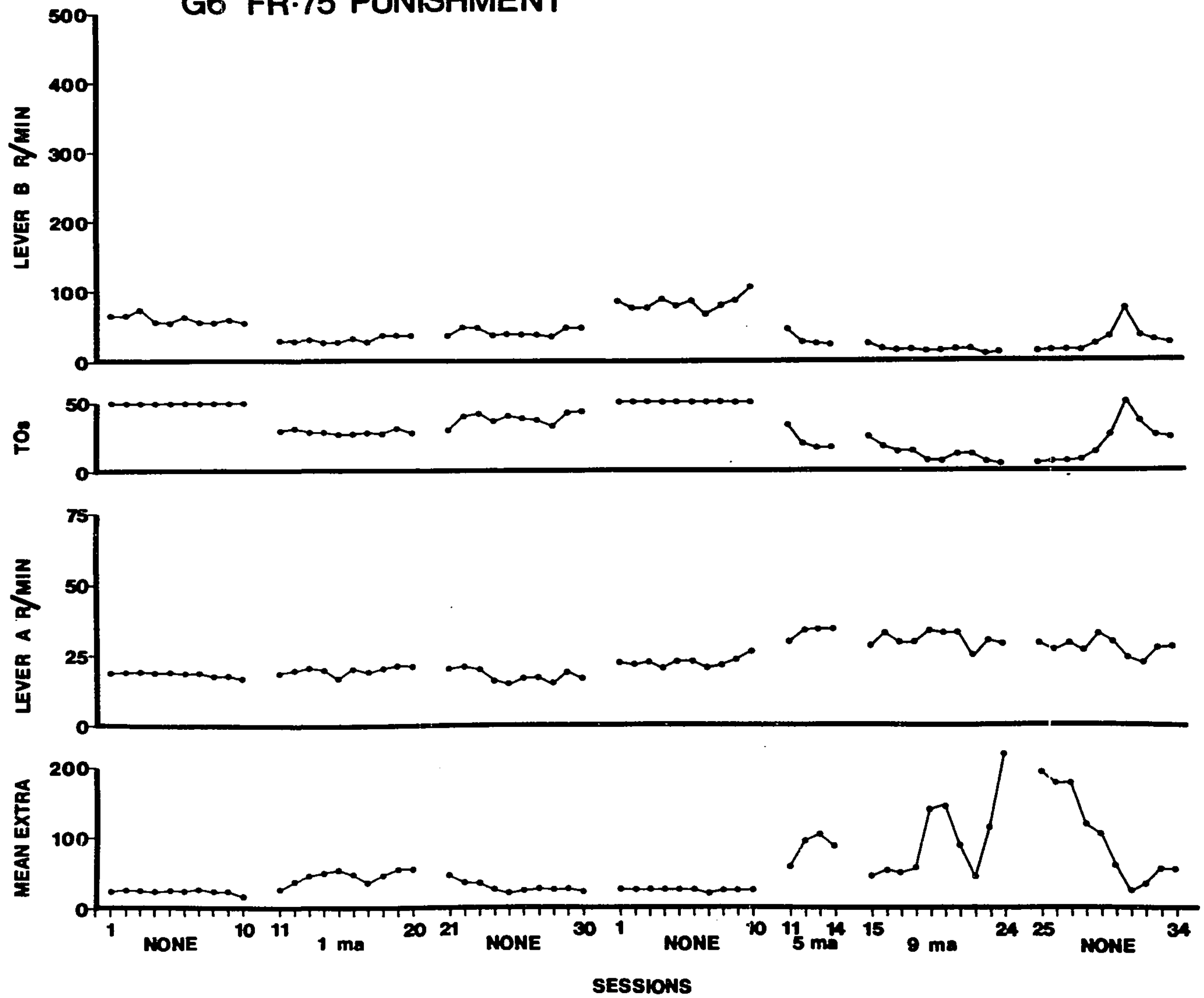


Fig. _28_. Representative cumulative records are shown for G6 during the FR-75 punishment condition. In the upper row pre-punishment performance on lever B is shown. The middle row gives a record of lever B performance on the second day of 1 ma shock, and the bottom record shows lever B performance on the seventh day of 9 ma shock. Oblique downward deflections of the pen indicate periods of time out; paper drive was halted during each time out period.

G6 FR·75 PUNISHMENT

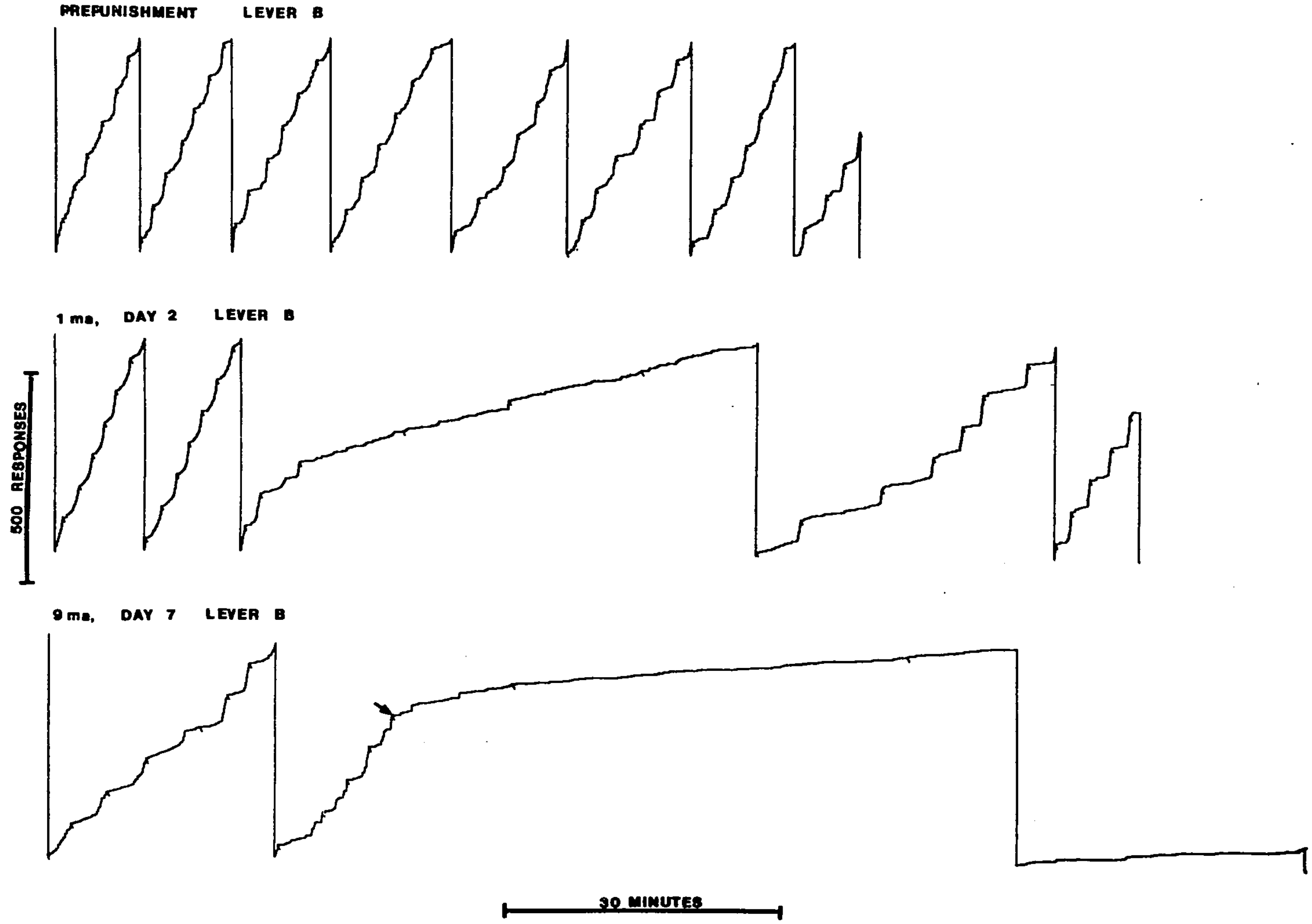


figure 28-9ma, day 7. The undifferentiated responding with rough grain emerged immediately following the shock and continued throughout the rest of the session.

G7: FR-75 punishment was the last punishment condition for G7. The same increase in rate of lever A responding and in number of extra responses that was found with the other animals occurred for G7 (figure 29). The increase in the number of extra responses continued after 12 ma punishment was discontinued. During two sessions the mean number of extra responses exceeded the 200 responses which was the maximum number the graph could accomodate. Sample cumulative records are shown in figure 30. By day 1 under 2 ma punishment, breaks in responding appeared on lever B. Note that the largest break in the record for lever B was accompanied by a high rate of responses on lever A. Under punishment of 5 ma shock, the record for day 1 showed breaks occurring at various parts of the ratio on lever B. The first break occurred shortly before the completion of the ratio (figure 30-5ma, day 1).

The record for day 1, 12 ma punishment again shows the first break occurring shortly before completion of the ratio. Scattering and bursts of responses occurred until the next ratio was completed. This scattering of responses with brief bursts and breaks occurring randomly throughout the ratio was the typical FR-75 punishment effect for G7. This animal differed from other animals only in that complete pausing was more frequent that the undifferentiated low rate which usually emerged with the other animals.

EXTINCTION

The extinction records obtained when TOav-reinforcement was removed after the 10th time out are shown in figure 31.

A tabulation of the avoidance rate, lever B rate, and shock rate is presented separately for the first 10 time outs (before

Fig. 29. In these graphs lever B responses per minute, number of time outs earned during the session, lever A responses per minute, and the average number of extra responses per time out are plotted for G7 during the FR-75 punishment condition. Each point represents a value for a single one of the 58 consecutive sessions. Values for each measure are given before punishment (sessions 1 through 10), during 1 ma shock (sessions 11 through 14), 2 ma shock (sessions 15 through 24), following punishment (sessions 25 through 34), during 5 ma shock (sessions 35 through 38), 9 ma shock (sessions 40 through 44), 12 ma shock (sessions 45 through 48), and following punishment (sessions 49 through 58).

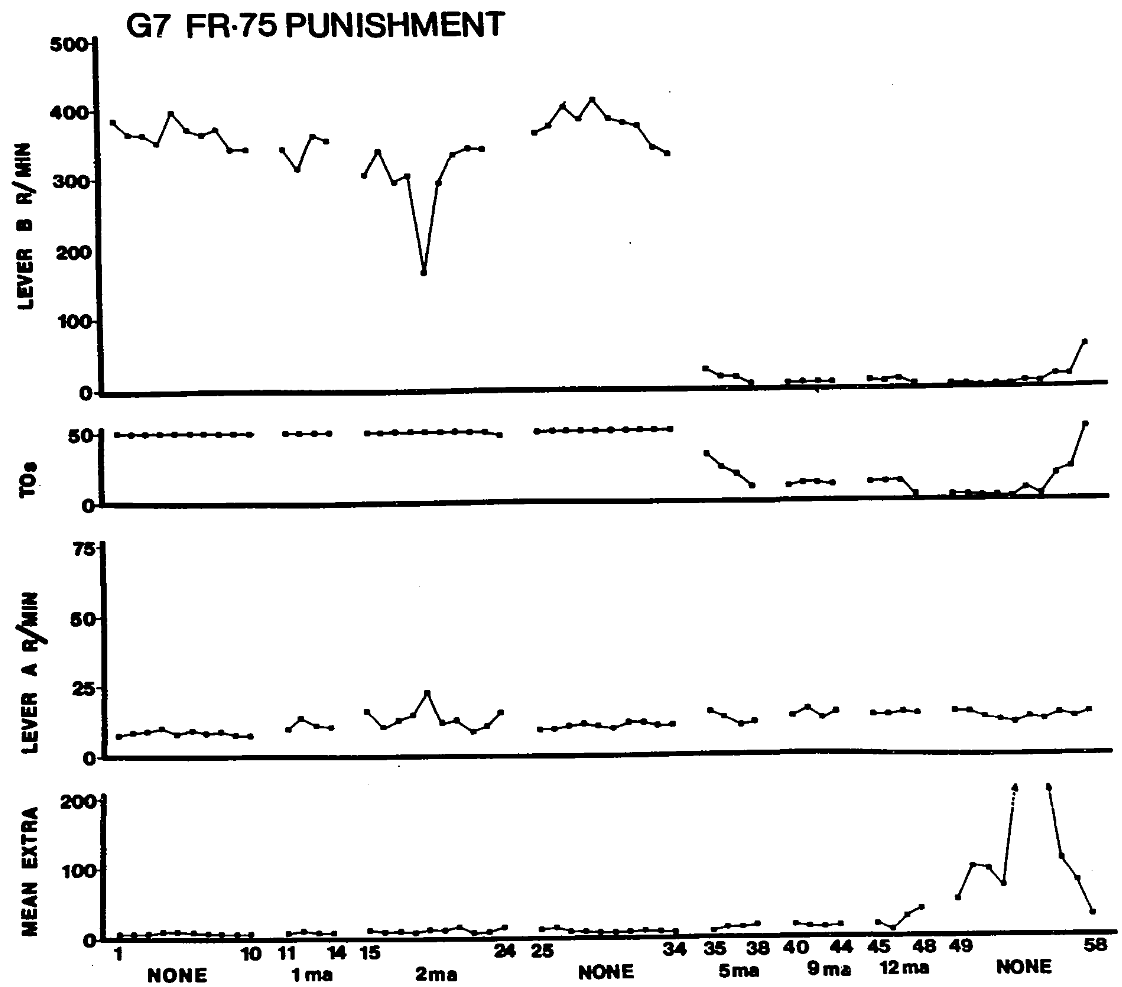

G7 FR·75 PUNISHMENT
LEVER B R/MIN
TOs
LEVER A R/MIN
MEAN EXTRA
0
100
200
300
400
500
50
25
75
1
10
11
14
15
24
25
34
35
38
40
44
45
48
49
58
NONE
1 ma
2ma
NONE
5ma
9ma
12ma
NONE

Fig. 30. Representative cumulative records are shown for G7 during the FR-75 punishment condition. In the upper row pre-punishment performance on lever A and lever B, and performance on both levers for the first day of 2 ma shock are shown. In the middle row a record of lever B performance on the first day of 5 ma shock is shown. At the bottom, performance on lever B for the first day of 12 ma shock is shown. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

Fig. _30_. Representative cumulative records are shown for G7 during the FR-75 punishment condition. In the upper row pre-punishment performance on lever A and lever B, and performance on both levers for the first day of 2 ma shock are shown. In the middle row a record of lever B performance on the first day of 5 ma shock is shown. At the bottom, performance on lever B for the first day of 12 ma shock is shown. Oblique downward deflections of the pen indicate shock deliveries when they appear on a lever A record and indicate periods of time out when they appear on a lever B record; paper drive was halted during each time out period.

G7 FR·75 PUNISHMENT

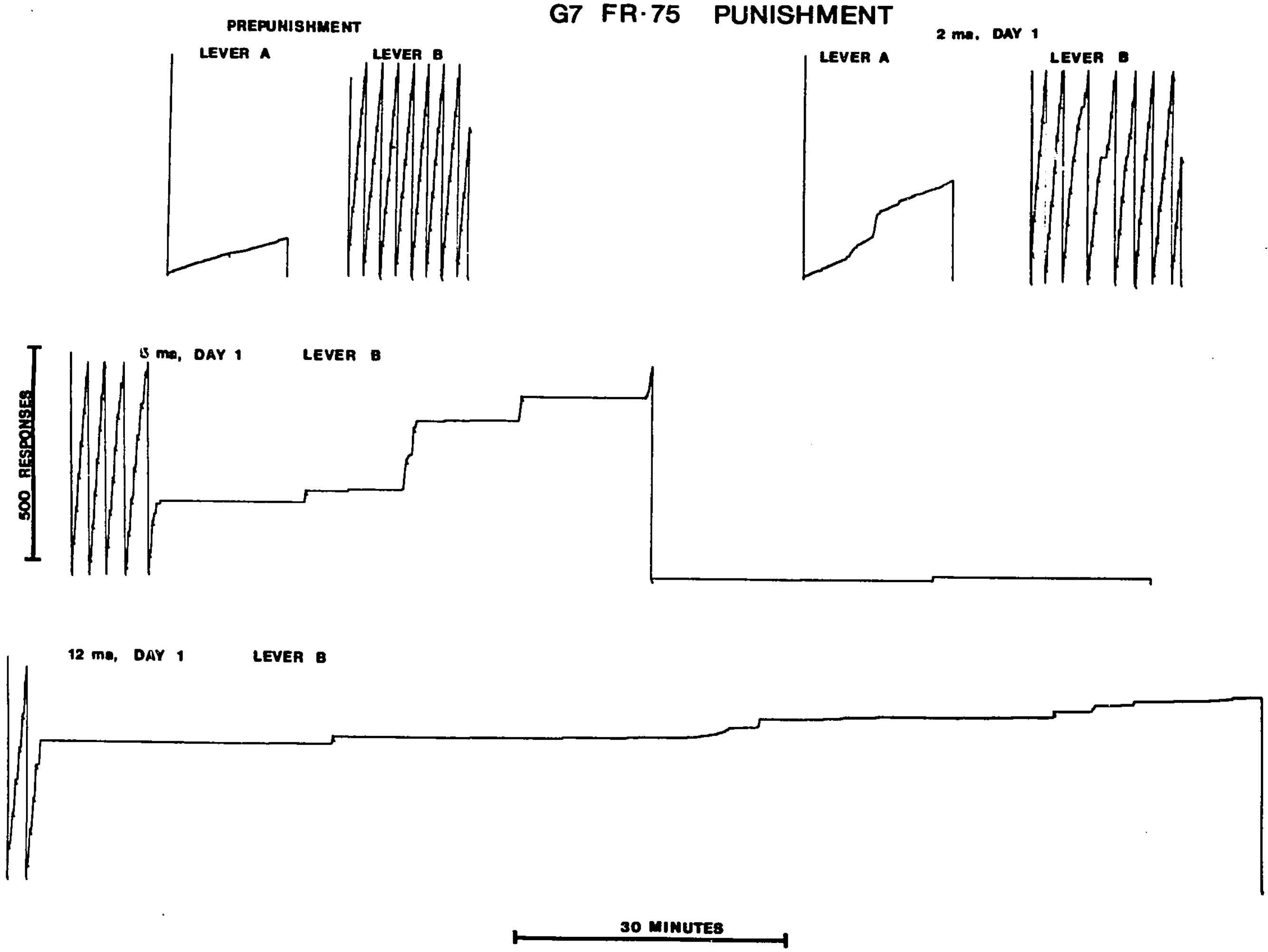
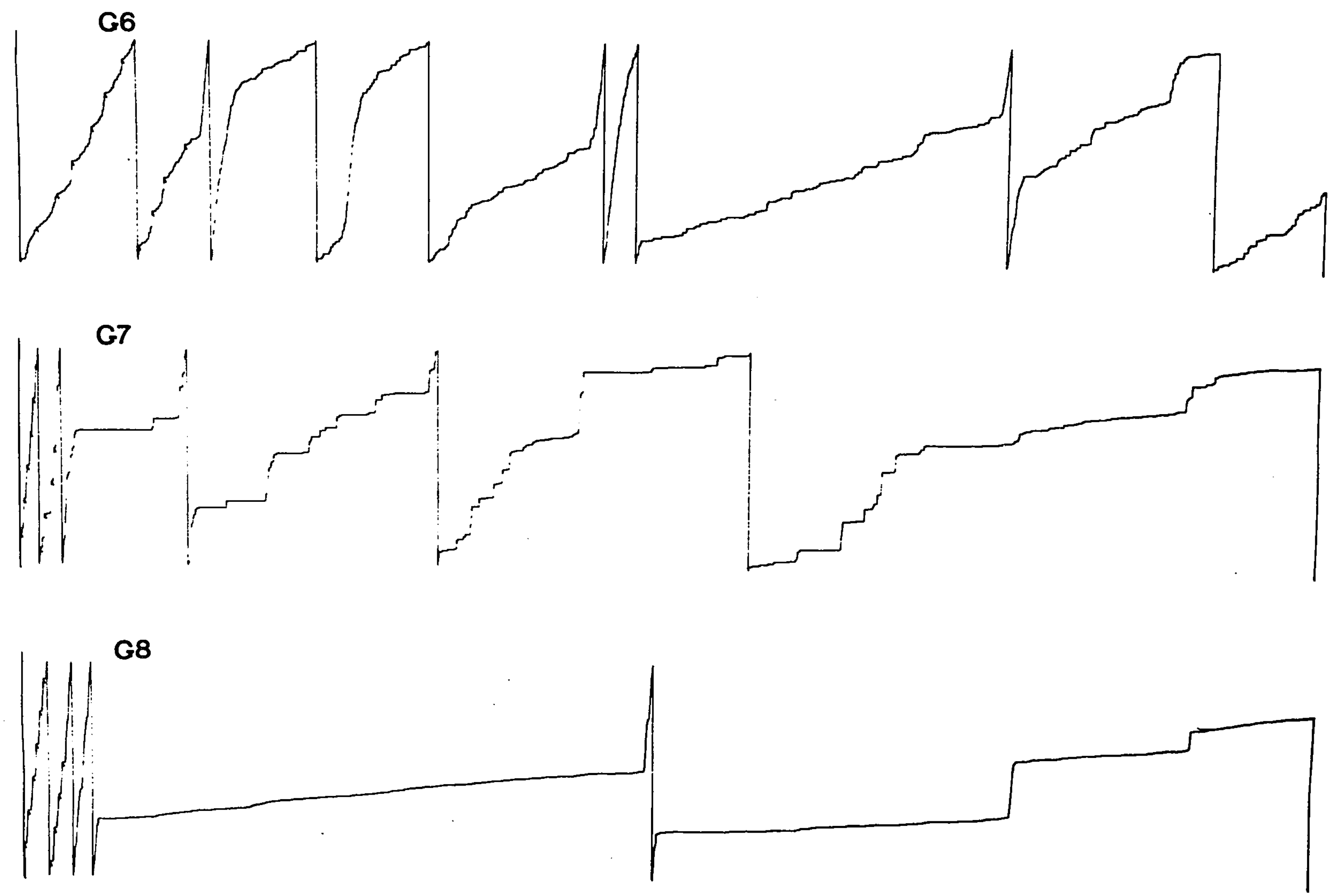


Fig. 31. Performance on lever B during extinction is shown for G6, G7, and G8. Oblique downward deflections of the pen indicate periods of time out; paper drive was halted during each time out period. After the tenth time out, reinforcement was removed (it was no longer possible to earn another time out). The session continued for the remainder of the $2\frac{1}{2}$ hours.

FR EXTINCTION (LEVER B)



extinction conditions) and for the remainder of the session. The complete session was 2½ hours long.

BEFORE EXTINCTION	G6	G7	G8
AV-rpm	14.01	12.72	12.21
FR-rpm	50.46	246.15	202.08
Total FR responses	825.00	832.00	778.00
Total shocks	0	0	0
DURING EXTINCTION			
AV-rpm	21.62	14.99	10.69
FR-rpm	37.34	22.09	16.52
Total responses	4099.00	2784.00	2077.00
Total shocks	0	20	28

SUMMARY OF RESULTS

FR-1 punishment: Punishment of the first response of the ratio led to long pauses on lever B following a time out. Upon delivery of punishment for the first effective response, a high rate was initiated which typically continued until the required 75 responses were completed.

FR-37 punishment: Punishment of the middle response of the ratio produced disruptions and lowered rate during the first half of the ratio, with delivery of the punishment shock initiating a high rate which continued until the time out was earned.

FR-75 punishment: Punishment of the last response of the ratio led to disruptions and breaks occurring throughout the ratio. Frequently a low rate emerged and continued throughout with no rapid bursts of responding appearing.

For all punishment conditions a heightened lever A rate tended to appear after punishment of ratio performance on lever B. This increase in rate was not directly shock-initiated as were the increased rates observed on lever B, but typically occurred prior to the delivery of punishment shock during the periods of low rate and disrupted responding on lever B.

Punishment effects were gradual rather than immediate and little recovery occurred.

Removal of TO-reinforcement on lever B produced an increase in lever A rate with two animals and a decreased lever A rate with the other animal. Responding on lever B continued throughout the session with runs of responding decreasing in length and rate lower toward the end of the session. Extinction on lever B was not complete at the end of the 2½ hour session.

Discussion

The present research was undertaken to explore how responses-contingent punishment affects behavior maintained by time out from an avoidance contingency.

Before discussing the findings it might be helpful to examine the problem of finding criteria for a punishment procedure. One of the more common definitions of a punishment procedure is that of making a noxious stimulus (or aversive stimulus or negative reinforcer) contingent upon a response. For example, Church (1963) suggests "the punishment procedure is one in which the noxious stimulus is absent and the response produces it." As Church recognized, this definition transforms the problem of defining punishment into a problem of defining a noxious stimulus.

Some theorists (Dinsmoor, 1954; Skinner, 1953) have recommended an escape criterion for a noxious stimulus. Using this criterion, when it can be demonstrated that an animal will learn a response which terminates a stimulus, that stimulus may be regarded as noxious. The major difficulty here is that few studies, including the present one, demonstrate the effectiveness of the noxious stimulus in maintaining escape behavior. Although shock has been used in many escape studies, its effectiveness varies with both intensity used and the individual subject. The advantage of using an escape criterion is that the effects observed in escape conditioning seem more reliable and less complex than effects of punishment procedures.

Another common criterion for a noxious stimulus is production of suppression when the stimulus is contingent upon a response. Sometimes, however, suppression is not obtained even with intense stimulation. In the present experiment, using this criterion, it would be necessary to assume that 12 ma shock was a noxious stimulus for G8 under FR-37 punishment, although not a noxious stimulus under conditions of FR-1 or FR-75 punishment. For other animals as well, the shock intensity which began to produce suppression varied with conditions.

The effectiveness of punishment depends on factors other than stimulus intensity, including stability of the on-going behavior, kind of previous training, and the drive level. This necessarily leads to difficulties whenever any behavioral change is used as a criterion for punishment. Since no precise and behaviorally-independent definition of punishment seems possible at this time, the term as used here refers to presentations of response-contingent stimuli which vary considerably in intensity. Shock intensities which generally produce some suppression are referred to as mild punishing stimuli, while intensities which frequently produce considerable suppression are referred to as strong punishing stimuli.

PUNISHMENT EFFECTS

Prepunishment performance: Baseline performance on the concurrent schedule sometimes showed curvature (note stabilized performance for G5 and G6, figure 4) rather than the more typical FR pattern of a pause followed by rapid responding. Similar FR curvature was obtained by Catania, Deegan and Cook (1966) on a concurrent FR-food and avoidance schedule with an ongoing avoidance program. The avoidance parameters determine the amount of switching back and forth between levers which is necessary to continue avoiding shock while completing the ratio. The same kind of curvature was apparent in the records obtained by Sidman (1962) for rhesus monkeys on a concurrent TOav schedule. He further quantified this pattern by analyzing the switching behavior between the levers. The number of avoidance responses decreased and the number of ratio responses increased as the animals neared completion of the ratio.

Punishment superimposed on this baseline behavior produced graded effects similar to those obtained in other studies by punishing ratio performance maintained by food reinforcement.

First-response punishment: Punishment of the first response of the ratio had a consistent effect of increasing the post-reinforcement pausing. Breaks rarely occurred at any point other than at the beginning of the ratio for FR-1 punishment. Similar results were obtained by Dardano and Sauerbrunn (1964b) and DeArmond (1966) when punishing pigeons for the first ratio response on a grain-reinforced FR schedule. However, they reported frequent breaks after the initiation of responding. Under FR-1 punishment the probability of response should be lowest at the beginning of the ratio due to the combined effects of the low probability of reinforcement and the high probability of punishment. This may account for the finding that FR-1 punishment produced the most consistent results. Under punishment of responses occurring later in the ratio, the tendency toward suppression produced by punishment would be working against the tendency to respond at a heightened rate when approaching the end of the ratio requirement. The punishment shock typically initiated a heightened lever B rate, surpassing the prepunishment rate, which continued until the ratio requirement was completed. This was particularly apparent for G5 and G6, since these were the two animals with obvious FR curvature under baseline conditions. Since the pigeons of Dardano and Sauerbrunn before punishment typically paused briefly after reinforcement and then responded at an uninterrupted rate until reinforcement, there was less opportunity to show rate acceleration under FR-1 punishment.

Middle-response punishment: Punishment of the 37th response led to disruption of responding during the first half of the ratio. Breaks occurred after responding was begun but little post reinforcement pausing appeared. Low rates frequently emerged following a time out and continued until the middle response was punished; the punishment shock then initiated a high rate of responding until the ratio was complete. As in FR-1 punishment, the shock-initiated rate was higher than the prepunishment rate. These findings are again consistent with the results obtained by Dardano and Sauerbrunn (1964b) with pigeons on a grain-reinforced ratio schedule. Aversiveness of the shock controlled the suppression early in the ratio. The shock delivery acted as a discriminative stimulus indicating that reinforcement would follow 37 shock-free responses. This cue effect of shock, resulting in a higher rate of responding than the previous stable rate, clearly illustrates that the effect of punishment is not always suppression of subsequent behavior. It might be expected that the FR-37 shock would initiate a higher rate than the FR-1 shock, since reinforcement is correspondingly closer in the former case. Indeed, this result was obtained by Dardano and Sauerbrunn. It must be kept in mind, however, that under the concurrent schedule used in the present study, a large number of lever A responses as well as ineffective lever B responses preceded the punishment shock. (The ineffective lever B responses are not shown on the cumulative records but appear on graphs showing the average number of extra responses.) The high number of total responses occurring before the punishment shock may have made the difference between 37 and 75 remaining lever B responses negligible. Thus the discriminative function of the shock (shock-free responding until reinforcement) was similar in the two cases.

Last-response punishment: Since there is an increased probability of responding near the end of the ratio it might be expected that this would offset the suppressive effects of FR-75 punishment. In a study by Dardano and Sauerbrunn (1964a) using increasing or decreasing intensities of shock in successive thirds of the ratio, responding during the last third of the ratio was found to be resistant to disruption. In that study, the change in shock intensity served as a cue that reinforcement was imminent. In the present research only a single response, the last one, was punished and marked disruption resulted. Breaks and disruptions occurred throughout the ratio. Although the breaks rarely occurred at the beginning of the ratio, they were not limited to the second half of the ratio. The first break to occur in the session frequently appeared near the end of the ratio, and since breaks never appeared after the middle response for punishment of the first or middle response this is a distinquishing feature of FR-75 punishment. Decelerations at the end of a ratio occurred occasionally. Rough grain and a low rate throughout the ratio was the most typical feature of punishment of the last response. This is consistent with Dardano and Sauerbrunn's finding (1964b) with punishment of the last response for pigeons. The effects of FR-75 punishment can be contrasted with the effects of FR-37 punishment by comparing the suppression patterns for G6 under the two conditions (figure 16 and figure 28). The first scheduled shock is marked by an arrow on the lower record in both figures. Under FR-37 punishment, a relatively low rate occurred during the first 10 time outs and during the 11th time out until the punishment shock was delivered; a rapid rate followed the punishment shock until the time out was earned. Under FR-75 punishment a relatively low and uneven rate again appeared for the first 11 time outs; after the punishment of the last response of the 11th period, a lower undifferentiated pattern emerged. Without shock as a discriminative stimulus for shock-free responding, runs of responding did not occur near the end of the ratio. Animals exhibited continuous switching back and forth between levers as though attempting to avoid an anticipated shock. Possibly response-contingent stimulation accompanying runs of responding acquired conditioned aversive properties because it was frequently followed by punishment shock. Switching behavior was less aversive; it was less frequently followed by punishment, since lever B responses during the COD were ineffective and increased switching led to a delay in reaching the 75th response.

Discrimination between avoidance shock and punishment shock: The increase in lever A responding with the introduction of punishment on lever B is consistent with research showing that rate of avoidance responding increases as a result of unavoidable shocks. Sidman, Herrnstein, and Conrad (1957) suggested that the effect of introducing free shock into an avoidance program is similar to the introduction of variable response-shock intervals and leads to "superstitions" avoidance behavior. Similar results were obtained by Kelleher, Riddle and Cook (1963) and Migler (1963). In these studies the avoidable and unavoidable shocks were of the same intensity. The increased lever A rate in the present study might also be interpreted as "superstitious" avoidance behavior. The punishment and avoidance shocks were rarely of the same intensity, however, and should have thus been more easily discriminable. In addition, the punishment shocks were contingent upon lever B responding. Appel (1960) found that monkeys could discriminate between avoidable shock and response-contingent shocks. In the present experiment the discrimination of a shock as contingent upon an FR response should not be as easy since shocks programmed under the avoidance schedule frequently occurred immediately after an FR response.

Three main sources of discrimination between prepunishment and punishment conditions are possible: (1) There was generally a difference between intensities of avoidance shock and punishment shock (2) Only during the punishment condition was it possible for a shock to occur shortly after an avoidance response. Since one of the initial effects of lever B punishment was an increase in the avoidance rate the occurrence of a punished response soon after a lever A response would become more likely. A time lapse of at least 2 seconds would still exist, but the difference between a 2 second and a 20 second period should be easily discriminable. (3) The discrimination could be based on the consistency of the occurrence of the punishment at the appropriate point in the completion of the ratio on lever B.

Gradual suppression and absence of recovery under punishment: Punishment did not lead to immediate suppression, so any discrimination that developed did so gradually. This is in contrast with the usual effects of punishment. Azrin (1959) found that reduction of responding was greatest at the time of the initial introduction (or increase) of punishment and that spontaneous recovery occurred within and between punishment sessions. Recovery effects were also obtained by Dardano and Sauerbrunn (1964b) and DeArmond (1966), using a concurrent schedule quite similar to the present one except for the use of food reinforcement rather than TOav reinforcement. No alternate means of obtaining reinforcement was available in the latter studies. Food reinforcement could be obtained only by responding in spite of the punishment. Perhaps the absence of recovery during punishment found here was due to the presence of an alternate response for avoiding shock. Holz, Azrin, and Ayllon (1963) and Herman and Azrin (1964) found that punishment was more effective when an alternate response was available, and that rate of the alternate response increased markedly under punishment of the first response. The increase in rate for lever A noted in this study under punishment of lever B responses seems to further justify viewing lever A as an alternate response. Although recovery effects were not discussed in the studies mentioned, it seems possible that the presence of an alternate response may reduce or eliminate recovery effects as well as increasing the effectiveness of punishment. This hypothesis requires further investigation.

The gradual suppression obtained is probably more related to the gradual development of a discrimination between punishment and prepunishment conditions. Gradual suppression was also obtained in the study by Appėl (1960) in which monkeys learned to discriminate between avoidable shock in one component of the schedule and response-contingent shock in another component of the schedule. In research which found immediate suppression (i.e. Azrin, 1959; Dardano and Sauerbrunn, 1964b; and DeArmond, 1966) the punishment shock was clearly and immediately discriminable from any of the prior conditions.

The gradual suppression obtained and the absence of spontaneous recovery suggest a need for qualification of some of the frequently mentioned characteristics of punishment. Azrin and Holz (1966, p. 411) in their chapter on punishment state that "Virtually all studies of punishment have been in complete agreement that the reduction of responses by punishment is immediate if the punishment is at all effective." This statement may be true only for punishment situations in which discrimination of the punishment condition is not an important variable. Spontaneous recovery within and between sessions was discussed by Azrin and Holz as another characteristic of punishment. The present study suggests that recovery under punishment may not be obtained, even for mild punishment, when an alternate response is available. Recovery was frequently obtained after punishment was removed under the mild punishment condition, but spontaneous recovery while punishment remained in effect was not observed.

Failure to obtain suppression: Some attention should be given to the failure to obtain suppression for G8 under FR-75 and FR-1 punishment.

In most studies which fail to show suppression under typically punishing conditions, the discriminative properties of punishment can help account for the findings. Some of these discriminative properties are discussed by Holz and Azrin (1961, 1962). These studies showed that generally effective intensities of shock can facilitate rather than suppress responding if shock is selectively paired with reinforcement. Discrimination is sometimes involved in more subtle ways, however. In the present experiment, G8 first learned how to avoid shock by pressing lever A and how to escape from the shock-avoidance stimulus complex by pressing lever B. If the animal failed to discriminate the punishment shock from a shock delivered on the avoidance program, behavior similar to that under the concurrent schedule prior to the introduction of punishment would be expected. Typical behavior for G8 under the concurrent prepunishment schedule when a shock occurred was brief responding on lever A to postpone further shock followed by rapid lever B responding to escape from the avoidance stimulus complex. G8 persisted in this form of behavior under punishment of lever B responding. This suggests a failure to discriminate between punishment and prepunishment conditions for FR-75 and FR-1 punishment.

Another possible interpretation is that the reinforcing properties of escape from conditioned aversive stimulation were greater than the aversiveness of the punishment shock. For two reasons this interpretation does not seem likely. If strong punishment were being pitted against strong reinforcement, behavior typically shown in conflict situations would be expected. Except for the disruption of efficient lever A responding little conflict behavior was apparent; responding on lever B was rapid with little switching between levers. A second objection is that this hypothesis would entail an additional hypothesis to account for the change in the relative strengths of the punishment and reinforcement under the final conditions when suppression occurred. It is not as awkward to suggest that the animal eventually discriminated between the two conditions, although this leaves unanswered the question of why G8 failed to discriminate when the other three animals did. A possible explanation may be found by a comparison of the performance of G8 on the concurrent schedule with that of the other animals. His behavior pattern in the experimental chamber appeared more rigid and stereotyped than that of the other animals. He responded briefly on lever A, then turned to lever B and responded rapidly until a time out was earned. Responding on lever B was invariably accompanied by a rhythmic foot-thumping which could be distinctly heard outside the chamber in spite of masking noise. The rigid behavior pattern and the minimal amount of switching may have influenced the animal's reaction to punishment shock. The other animals more readily reacted to punishment with increased switching to lever A. This increase in switching initially occurred following the shock and later began to occur prior to the shock. Any lever A responding postponed the punishment shock for at least the 2 second COD (change over delay) period. Perhaps because of this relationship between lever A responding and absence of punishment shock, rate on lever A tended to increase for the other animals. G8 persisted in his prepunishment pattern of responding on either lever A alone or lever B alone without a smooth integration of the two responses. This is apparent in his extinction record (figure 31) in which he persists at lever B responding through many shocks before switching abruptly to lever A. Rate on lever B is either quite high or quite low, in contrast with the more intermediate rates for the other two animals. The other animals emitted more total lever B responses, but received fewer shocks because of the smooth alternation between the two levers. This virtual punishment of lever B responding perhaps accounts for the finding that G8 made only 2077 total lever B responses during extinction, compared with 2784 for G7 and 4099 for G6.

Extinction: The effects of extinguishing responding on the ratio schedule were similar to the effects obtained in similar schedules using food reinforcement rather than TOav-reinforcement (Catania, Deegan and Cook, 1966; Kelleher and Cook, 1959). Duration of high response rates became less prolonged as the session proceeded, and a large number of ratio responses were emitted during the 2½ hour session. Removing the reinforcement for the ratio schedule had the effect of increasing the rate of avoidance responding in two of the animals and decreasing rate in one. This is consistent with the work of Catania, Deegan, and Cook (1966); they used monkeys on a concurrent avoidance and food-reinforced ratio schedule and found extinction on the ratio schedule produced increased avoidance rate in half of the animals and decreased rate for the rest.

Both Catania, Deegan and Cook (1966) and Kelleher and Cook (1959) reported no increase in avoidance shocks as a result of extinction of the ratio component. The present research showed an increased avoidance shock rate for two of the animals, while the third received no shocks. The increased shock seemed to be related to the behavior of the animals on the concurrent schedule. G6, who typically alternated a few avoidance responses with short runs of ratio responding, continued this after removal of the FR component and received no shocks. The two other animals (G7 and G8) typically emitted a few avoidance responses and then completed the entire 75 ratio responses in a single long run. G7 was not as rigid in this behavior as G8 and occasionally switched to lever B in the middle of the ratio run.

The number of shocks received during removal of the ratio schedule is inversely related to the amount of prior switching behavior. G6 received no shocks, G7 received 20 shocks, and G8 received 28 shocks. No direct count of amount of switching is available but switching behavior is closely related to the number of extra responses (figures 5 and 6). It is clear that G6 exhibited the most switching and G8 exhibited the least. Another check on the amount of switching can be made by a close examination of FR performance; breaks occurring on the record of ratio performance are typically accompanied by lever A responding.

It is also interesting to note that the number of total responses emitted on lever B during extinction is inversely related to the number of shocks received. This is reasonable, since shocks delivered under the avoidance schedule amounted to a virtual punishment of lever B responses. The greater the punishment for ratio responding, the more rapidly suppression occurred.

Metastability: Two different patterns of performance obtained under the same schedule parameters for the same animal, one before and one after an intervening condition, have been described as metastable (Staddon, 1965). Morse and Kelleher (1966) suggest that metastability may be a typical characteristic of performance under schedule-complex termination. The phenomena of metastability was observed in the present experiment. Marked differences in pattern of stable performance before and after intervening punishment conditions were exhibited. This can be illustrated by observing G5's baseline behavior for FR-1 punishment (figure 8) with his baseline behavior for FR-37 punishment (figure 20). This type of change in baseline made it essential to evaluate each punishment effect with the particular prepunishment performance for that condition. No single baseline existed for any animal.

OVERVIEW

Punishment of FR behavior maintained by TOav showed many of the characteristics of punishment of FR behavior maintained by food reinforcement. Changes in pattern emerged which were dependent on the point in the ratio at which punishment was delivered; these were consistent with the findings of Dardano and Sauerbrunn (1964b) for punishment of food-reinforced ratio responding. Both discriminative and aversive functions were apparent. Discrimination of the punishment shock as distinct from avoidance shock appeared as one important variable. This is not a consideration when food is used as reinforcement. Exceptions to the usual effects of punishment were noted in the gradual development of suppression and in the absence of spontaneous intersession and intrasession recovery effects. These seemed to be related to gradual discrimination of the punishment condition and to the presence of an alternate response, respectively.

An evaluation of the strength of the reinforcement value of TOav remains difficult. Many of the findings suggested a comparability of TOav and food reinforcers. The resistance to suppression shown under some punishment conditions might suggest a superiority of TOav over food. A confusing variable, that of discrimination of avoidance shock from punishment shock, makes comparison in these terms difficult. The absence of recovery might suggest that strength of TOav as a reinforcing agent is less than that of food. Again, however, a confusing variable must be considered. In the studies showing recovery under punishment for food-reinforced performance, no alternate means of obtaining reinforcement was available. In a concurrent avoidance and TOav schedule, an alternate response is built into the schedule. The amount of work involved did not emerge as a major factor. This is not surprising since Dardano and Sauerbrunn (1964c) found that pigeons would endure marked increases in work output rather than have a response punished. Any influence of aversiveness of work output was obscured by the strength of the aversiveness of the punishment and avoidance shocks. Some additional variables that emerged were shock intensity, count in the ratio, punishment sequence, and previous stabilized baseline.

Results were frequently complex and difficult to interpret. Due to the increase of lever A responding frequently observed during punishment, the COD periods were increased; this led to greater numbers of ineffective (extra) lever B responses and made time outs more difficult to earn. It was not possible to separate the effects of the increased number of required lever B responses from the effects of punishment. It is safe to conclude, however, that TOav can maintain stable ratio performance and that punishment of this behavior produces effects qualitatively similar to those obtained when other more conventional reinforcers are employed.

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