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BEHAVIORAL INTERACTIONS UNDER NOXIOUS ENVIRONMENTS.(U)

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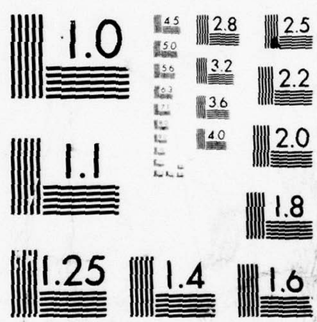

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REPORT NUMBER 2

Behavioral Interactions Under Noxious Environments

Annual Report

James E. Barrett

September 1978

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701

Contract No. DAMD 17-77-C-7001

Department of Psychology
University of Maryland
College Park, Maryland 20742

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This program has focused on an analysis of behavior and behavioral interactions under conditions where the main controlling consequences are noxious events (electric shock). Throughout the past year the primary efforts have been on understanding specific factors contributing to the varied effects of noxious environments on behavior.

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Summary

This research program has continued its emphasis on an analysis of behaviors occurring under predominately noxious environmental conditions. The primary interest in these studies has consisted of an analysis and ultimate understanding of the following general points: i) the effects that changes in the consequences of one behavior have on other aspects of that individual's behavior (behavioral interactions); ii) factors contributing to the development, maintenance and cessation of behavior by noxious consequences; iii) the effects on behavior of certain stimuli that are associated with the presentation of noxious events. Progress in specific experiments over the past year has consisted of further developing behavioral performances maintained by the termination, postponement or presentation of electric shock and stimuli correlated with each of these conditions. Of particular interest to this project has been an examination of certain factors contributing to the eventual maintenance of behavior solely by shock presentation. Thus far we have concentrated primarily on the role of the organism's prior behavioral experience or past history. Once these behaviors are developed and reliably maintained, we then focus on the manner in which they are subsequently modified by changes occurring elsewhere, under different conditions, as well as by more direct changes in other aspects of the experimental situation. Extremely orderly and reproducible behaviors have been successfully developed and maintained under all of these conditions simply by different arrangements of a single noxious event. Under some of these conditions this noxious event suppresses responding (punishment) and, under others, it maintains high levels of responding (reinforcement). Under still other conditions, shock is simultaneously presented and postponed. Knowledge of the different ways that an identical stimulus such as electric shock affects behavior has provided much information on the role of factors contributing to the varied effects that noxious events have on behavior. As a result, these studies have contributed substantially to an understanding of behavior under noxious environmental conditions.

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Foreward

In conducting the research described in this report, the investigator adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences-National Research Council.

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Introduction

Behavior is affected by a wide variety of environmental events. Some events precede certain responses and can be said to elicit those behaviors. Such behaviors, referred to as respondent behaviors, do not typically undergo progressive differentiation. Other behaviors, however, termed operant, are affected by events that follow their occurrence and usually, as a result, are differentiated in form, frequency and temporal patterning of occurrence. Consequent events that so increase the subsequent frequency of behavior are usually classified as reinforcers and those that decrease behavior are referred to as punishers (see Annual Report Number 1 of this contract for an elaboration of the processes of reinforcement and punishment).

Although it has often been assumed that reinforcers and punishers refer respectively to "good" and "bad" things, ample evidence now exists to warrant the conclusion that the behavioral effects of consequent environmental events cannot be attributed solely to the nature of those events. Work completed during the first two years of this contract has demonstrated that an identical event, electric shock, can both suppress and maintain behavior at about the same time and in the same organism (see Annual Report Number 1). The present report provides additional evidence bearing on the multiple behavioral effects of noxious stimuli and further describes progress during the past year. In all of the experiments outlined below, the major objective has been on a rather exhaustive analysis of factors affecting behaviors under predominately noxious environmental conditions. The different specific experiments, their procedures and results are given below.

General Experimental Methods

Healthy adult squirrel monkeys (Saimiri sciurea) were used as subjects in all of these studies. The monkeys were maintained in individual cages except when removed for daily one-to-three-hour sessions. In some cases body weight was reduced to 80 percent of the unrestricted feeding levels.

Experimental studies were conducted in a primate-restraint chair furnished with response devices, visual stimuli and methods of delivering food and electric shock. The distal end of the tail was shaved and, during experimental sessions, was held immobile by a small stock. Prior to each session the tail was massaged with EKG-sol electrode paste. Electric shock was delivered from a 650 V a. c. source to two brass electrodes that rested on the shaved portion of the tail. Shock duration was 200 msec with the intensity varied, depending upon the specific experiment. During the session the chair and restrained monkey were placed inside sound-attenuating cubicles that were also equipped with white masking noise.

In experiments using shock postponement or avoidance schedules, shocks were usually scheduled to occur every 5 seconds; a response postponed shock for 25 seconds. Unless otherwise noted, this procedure served as the initial phase for all experiments in which responding was maintained by shock presentation. It should be noted, however, that training under shock-postponement schedules is not necessary for the development and maintenance of responding by response-produced shock (cf., Kelleher and Morse, 1968; Morse and Kelleher, 1977; and McKearney and Barrett, 1978). In some experiments the shock-postponement schedule was removed upon introduction of the schedule of shock presentation, whereas in other studies both schedules were in effect simultaneously for a brief period (5-10 days) prior to the removal of the avoidance schedule.

Changes in experimental conditions were made when responding was stable over at least a one-week period. Usually a condition was in effect for at least 15-20 sessions before changes in the schedule were made.

Behavioral Interactions Under Multiple Schedules

Many of the experimental studies conducted over the past year have utilized multiple schedules in which two different visual stimuli are used to arrange different response consequences. Initially, performances and schedule conditions are comparable and then changes are made in only one of the conditions or components. In general, these experiments have had as their primary objective an analysis of those changes that occur in behavior under the one (unchanged) condition as a result of the experimental manipulation that occurred in the alternate component.

Previous studies have reported substantial modifications in behavior have occurred under one condition that resulted from a change in behavioral consequences occurring elsewhere (e.g., Reynolds, 1961a, b). Findings such as these indicate that behavior can be affected not only by its more immediate consequences, but also by consequences which may often be temporally quite remote. Very little information exists, however, on the nature and extent of such interactions under circumstances where the control of behavior is by noxious stimuli. Several different situations have been examined in detail under this contract and the results are given below.

Behavioral contrast

The initial phases of this experiment were described in last year's report. Essentially, after preliminary training under a shock-postponement schedule, responding was then maintained under 3-minute variable-interval (VI) schedules of shock presentation. Under this schedule a response produced an 8 mA shock on the average of once every 3 minutes. During the beginning phases of this study two different visual stimuli (red and white lamps) alternated every 3 minutes and the 3-minute VI schedule was in effect during each stimulus. When responding was stable and comparable in both components, the schedule was modified so that in the presence of white lamps responding had no scheduled consequences (i.e., extinction). It was under conditions such as these, with food presentation as the maintaining event, that increases in responding have occurred under the component where the VI schedule remained in effect (Reynolds, 1961a, b). An elevation in response rates under the unaltered condition (behavioral contrast) when shock presentation maintains responding would extend the conditions under which food and shock produce similar effects on behavior.

At the time of submission of last year's report it was not yet clear whether contrast was occurring under the VI shock-presentation extinction schedules. That experiment was continued until the outcome was clear. The results are presented in Figure 1 (page 9), which also includes data from the same monkeys collected during the previous year (MS-12 and MS-32). Behavioral contrast did occur, although only with one of the three monkeys (MS-32); even with this subject, however, an elevation in response rates in the unchanged component did not reliably accompany decreases in behavior occurring during extinction. Typically, responding maintained under the VI schedule was unaffected (e.g., with MS-12 at E and G), or there was a decrease in responding under the VI that accompanied decreases in responding during the extinction component (induction). These latter changes occurred both with MS-32 (phase labeled D) and MS-12 (phase B). At other times, with MS-32 only, contrast did occur (phases B and G) but when the extinction schedule was removed, responding during the unaltered component remained high and rates during the former extinction component rose to that level. Thus, contrast occurred relative to response rates existing prior to the introduction of extinction, but not relative to that existing after the VI schedule was reintroduced.

Findings such as these make it difficult to draw definitive conclusions either about the generality of the effects or about the similarity of such effects to those obtained when food is used as the maintaining event. Recently, a number of theoretical issues concerning behavioral contrast have been raised and a number of variables implicated (Schwartz and Gamzu, 1977). Factors such as the species, nature of the response and schedule value have all been shown to play a role in determining contrast (e.g., Hemmes, 1973; McSweeney, 1978). It is possible that any one of these factors could also contribute to determining the outcome of the experiments summarized above. In view of the ambiguity of the results, not only with the research using shock, but also with those using food, further work on these experiments was discontinued.

<u>Escape responding and punished responding</u>

Another study that was continued during the past year has focused on an analysis of behavior under conditions where responding is maintained by the <u>termination</u> of a stimulus correlated with the delivery of electric shock (typically referred to as a stimulus-shock complex termination schedule or sometimes simply as escape). Under this schedule repetitive shocks are scheduled to occur after a specified time period has elapsed and a single response after that fixed time terminates the stimulus-shock schedule and prevents further shocks (fixed-interval or FI schedule). Under a fixed-ratio (FR) schedule, a specified number of responses must occur before the stimulus-shock complex is terminated. These schedules usually further specify a time period between the end of the FI and the first scheduled shock (known as <u>t</u>) or a period of time within which the FR can be completed before shocks occur (usually known as a limited hold). Thus, under both FI and FR schedules, with appropriate <u>t</u> or limited hold values, it is possible to respond at a high enough rate to prevent the occurrence of shocks. It is also important to point out that schedules of stimulus-shock termination can produce patterns and rates of responding that are strikingly comparable to those maintained

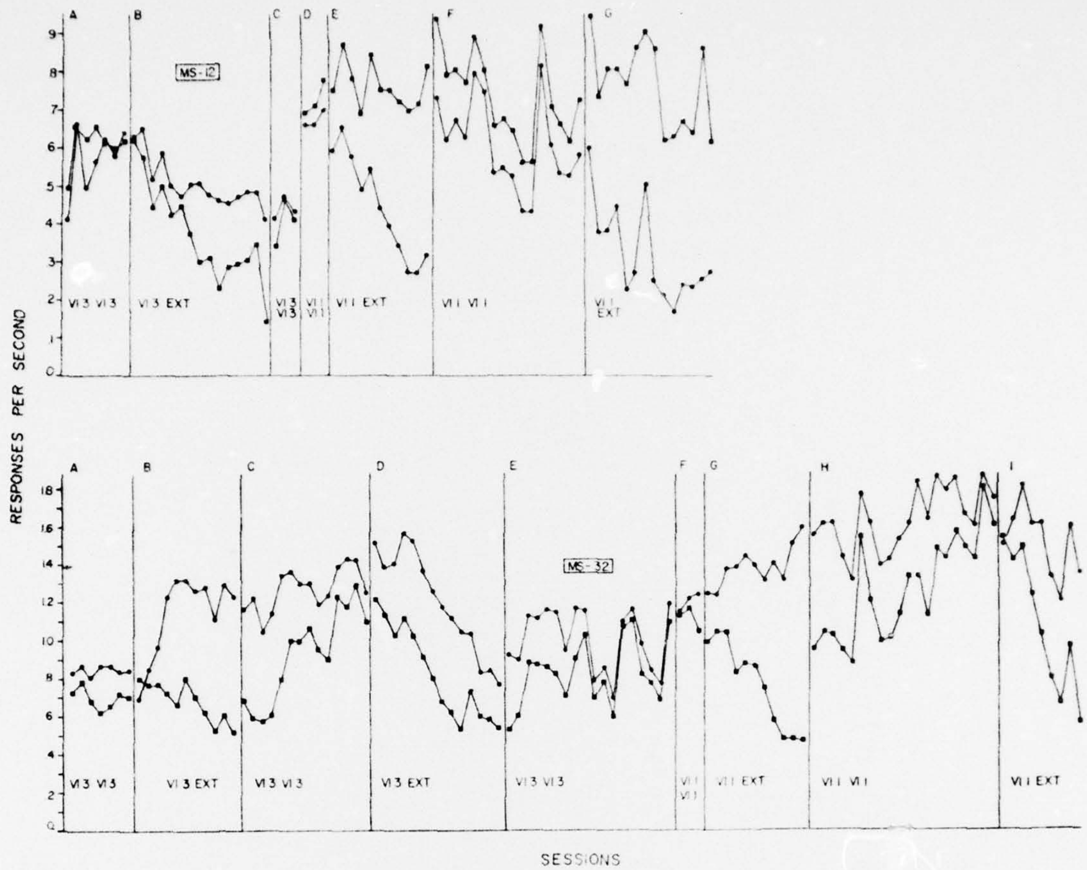

FIGURE 1

Changes in rate of responding under the multiple variable-interval schedules of response-produced shock and extinction. Circles represent response rates during the unchanged variable-interval condition; squares represent responding during extinction. See text for complete description of results.

by the presentation of food (see Figure 2, page 11, and the Progress Report from last year).

In some of the experiments conducted during the past year we have maintained responding under multiple FI stimulus-shock termination schedules and have then examined the effects of i) punishing responding in one component and ii) of changing the value of t in each component. Broadly, these studies have had as their primary objective an assessment of potential interactions occurring under escape schedules where responding in one component is punished and then the features of the schedules controlling behavior are then modified.

Figure 3 (page 12) shows performances maintained under the multiple 5-minute FI schedule where the t value was set at 3 seconds and where responding initially was not punished in either component. Shock intensity was 7 mA, whether occurring under the punishment or termination schedules. This figure also shows the subsequent punishing effects of scheduling shock presentation following every thirtieth response under one component of the multiple schedule. Responding declined substantially during the punishment component and also showed a slight tendency to decrease during the alternate component. Average unpunished rates for MS-25 and MS-9 were 1.671 and .44 responses per second, respectively. With punishment in effect, unpunished rates declined to 1.393 and .35 responses per second for MS-25 and MS-9, respectively; punished response rates for MS-25 were 0.096 responses per second and for MS-9 were 0.23 responses per second. Thus, when responding maintained by the termination of a stimulus-shock schedule was also punished by shock presentation, there was a corresponding reduction, although slight, in unpunished response rates occurring under an alternate stimulus condition (induction).

In the next phases of this study the t value in the unpunished component was decreased from 3 to 1 second and then to 0.5 seconds and finally 0 seconds. With a t = 0, shock was inevitable upon the elapse of the interval and a response at that time prevented further shocks that were scheduled to occur at 0.5 second intervals and produced timeout. Subsequently, the t was returned to 3 seconds and then the FR 30 shock-presentation schedule was removed for approximately 30 sessions. Rates of responding during the punishment component rose rapidly to over 2.50 responses per second for MS-25, well above rates in the alternate condition where responding did not change markedly. Increases in punished responding of this magnitude upon removal of the FR 30 schedule did not occur for the other monkey, MS-9, but were noticeably increased.

Table 1 (page 13) provides a summary of the effects of changes in the value of t during the component in which responding was not punished. Although there were few systematic changes in unpunished responding, punished response rates generally decreased at the lower values of t. With MS-9, responding was nearly eliminated in both components after only 5 sessions exposure to t = 0. This abrupt decrease required the removal of the FR shock schedule and an increase in the value of t to 3 seconds before responding was reestablished.

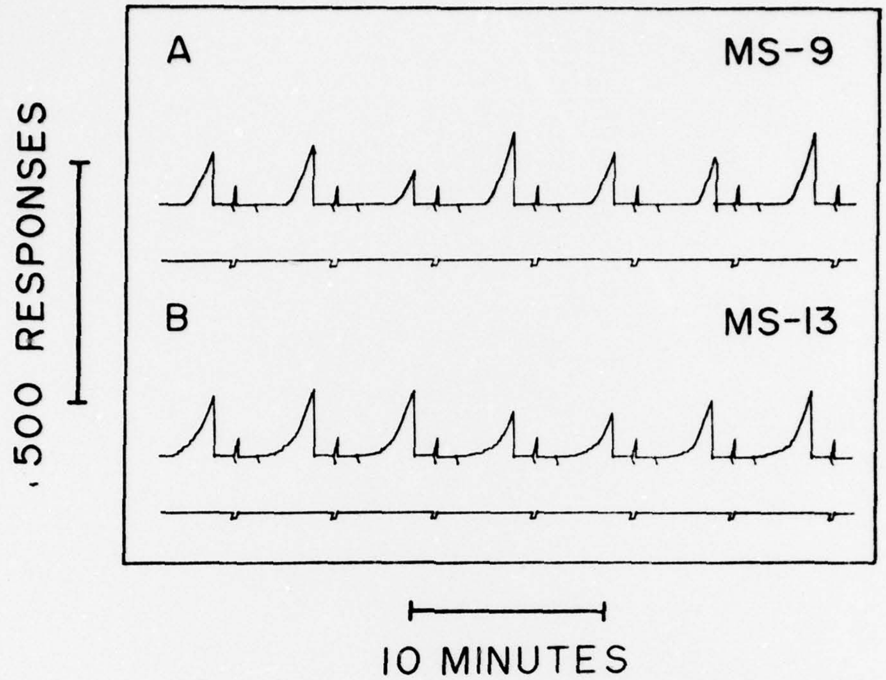

FIGURE 2

Cumulative response records of comparable performances maintained under multiple fixed-interval 3-minute fixed-ratio 30-response schedules of stimulus-shock termination (MS-9, top) or food presentation (MS-13, bottom). Abscissa: time; ordinate: cumulative responses. The event pen (lower line in each record) was displaced during the fixed-ratio schedule component. A one-minute timeout period separated each component, with the end of the timeout indicated by a diagonal slash on the record. Shocks delivered under the termination schedule occurred 3 seconds after the elapse of the 3-minute interval (and are indicated by a slash of the response pen, e.g., see the second interval for MS-9); under the fixed-ratio a shock was scheduled to occur 30 seconds after the onset of that component. No shocks occurred under this schedule in the records shown. Under the food schedule if a response was not made within a one-minute period after the end of the fixed-interval of after 30 seconds under the fixed ratio the component ended automatically without food. Note that performances under the two schedules differed depending on the schedule but not on the event.

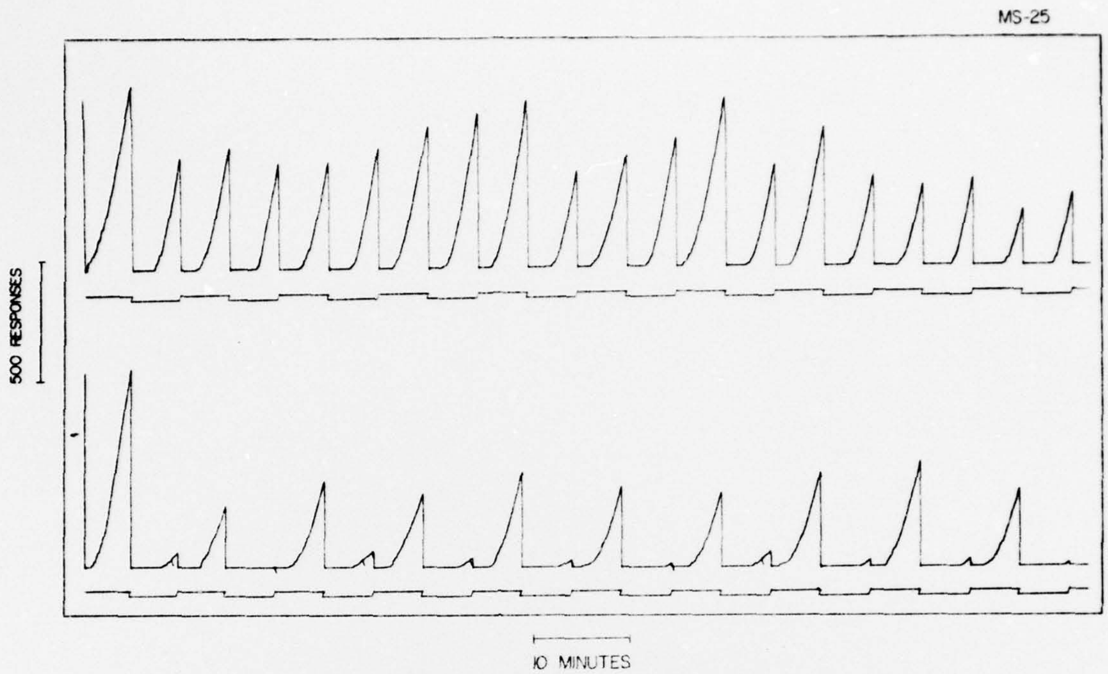

FIGURE 3

Cumulative response records of responding under multiple 5-minute fixed-interval schedules of termination of a stimulus-shock complex. Method of recording as in previous figures. In the top record responding was not punished and comparable rates of responding were maintained in each component. The lower record shows the effects of arranging a schedule in which every thirtieth response during one component (event pen displaced) also produced shock and suppressed responding (punishment).

TABLE 1

Effects on rates of punished and unpunished responding (responses per second) of variations in t during the nonpunishment component.

t value (seconds)	MS-25 Unpunished	MS-25 Punished	MS-9 Unpunished	MS-9 Punished
0	1.866	.084	.023	.004
0.5	2.354	.146	.435	.013
1.0	1.800	.112	.458	.020
3.0	1.393	.096	.350	.231
	(1.100)*	(.140)*	(.536)	(.019)

* Redetermined after all other values were examined. The sequence of conditions was 3.0, 1.0, 0.5, 0 and 3.0 seconds. Data based on the mean of the last three sessions at each condition.

In the next phase of this experiment, with responding punished during the one component again, changes in the value of t were made during the punishment component. Those results are summarized in Table 2 (page 14) for both monkeys. Generally, rates of unpunished responding increased with corresponding decreases in t during the alternate punishment component. These effects were a bit more consistent with MS-9. Punished responding, however, decreased systematically with decreases in t for both monkeys.

The results of these experiments demonstrate convincingly that when responding is maintained under stimulus-shock complex termination (escape), sometimes sizeable interactions can occur between punished and unpunished responding. In this experiment punished responding decreased regardless of whether decreases in the value of t occurred in that component or in the alternate component. Similar changes occurred in unpunished responding when t was manipulated only in the alternate punishment component. Despite the fact that these interactions occurred irrespective of the component in which changes were made, the nature of the interaction did differ. Decreases in t in the nonpunishment component generally decreased rates in both components (induction); decreases in the t value during the punishment component also decreased punished response rates but increased unpunished rates during the alternate unchanged condition (contrast).

TABLE 2

Effects on punished and unpunished responding (responses per second) of changes in the value of t during the punishment component.

t value (seconds)	MS-25 Unpunished	MS-25 Punished	MS-9 Unpunished	MS-9 Punished
0	1.286	.083	.778	.011
1	1.153	.120	.733	.031
3	1.398	.142	.718	.040
10	1.131	.152	.644	.056

The sequence of conditions was 3.0, 10.0, 1.0, 0, 3.0 seconds. Data represent the mean of the last three sessions at each t value.

Reinforcement and punishment of behavior by the same event

In this study we have been analyzing interactions between behaviors that are maintained and suppressed by the same electric shock under different components of a multiple schedule. Initially two monkeys were trained under a multiple schedule where, in the presence of red stimuli, an avoidance or shock-postponement schedule was in effect; under different conditions, associated with white stimuli, a 10-minute FI food-presentation schedule was in effect. During a second phase the avoidance schedule was removed and a 10-minute FI shock-presentation (10 mA) schedule was programmed. Thus, during this portion, responding was maintained under identical FI schedules with food as the maintaining event in one condition and shock as the maintaining event in the other. Figure 4 (page 15) shows rates and patterns of responding occurring under this portion of the study. This figure also depicts the effects of adding an FR 30-response shock-presentation schedule to the component in which food was delivered. Food-maintained responding was markedly suppressed by shock during this component of the schedule, yet it was still maintained at high rates during the alternate stimulus. The same electric shock exerted dual effects on behavior, depending on how it was scheduled.

We have examined several conditions under this schedule to assess the extent of potential interactions between shocks that both maintain and suppress responding. In various phases the FR 30 (punishment) shock schedule has been removed and subsequently reinstated, then the FI shock was deleted.

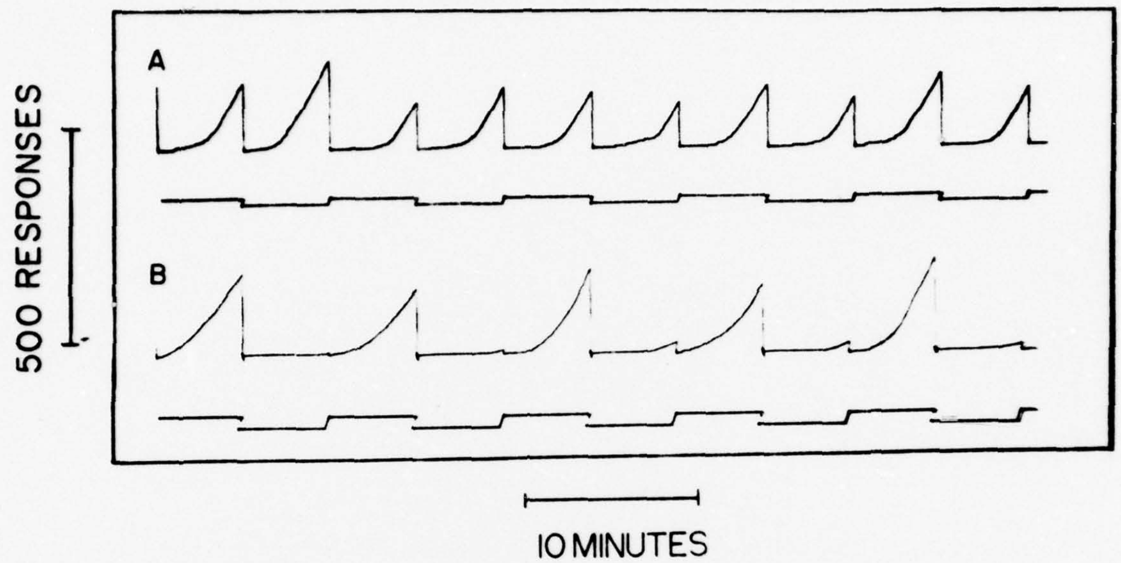

FIGURE 4

Cumulative records of responding maintained under multiple 10-minute fixed-interval schedules of either food or shock presentation (top record). The event pen was displaced during the component in which shock presentation maintained responding. The suppression and maintenance of responding by the same electric shock is shown in the lower record. Punishment shocks, delivered under a fixed-ratio 30-response schedule, markedly suppressed food-maintained responding; the same electric shock, however, continued to maintain high rates during the alternate component.

Thus far the effects of these manipulations has been confined to the component in which they occurred, showing little interaction between conditions. This experiment is continuing in an effort to examine more closely the effects on shock-maintained responding of substantial reductions in punished behavior. The several facets of this study, the near-simultaneous maintenance and suppression of behavior by the same consequent event promise to reveal much information about the processes of reinforcement and punishment and interactions between behaviors controlled in this manner.

Behavioral Interactions Under Concurrent Schedules

In all of the experiments described above we have focused on an analysis of situations where interactions could exist between sequentially-occurring behaviors. As indicated above, these studies have provided a means of experimentally separating behaviors both in time and in terms of controlling stimuli. Despite this separation, it is quite clear that when the consequences of behavior in one situation are altered, subsequent changes in behavior are not restricted only to that situation in which the behavior occurred.

Our research has also examined in detail another schedule which also has direct applicability to an understanding of behavior occurring under noxious environments. These experiments utilize concurrent (rather than multiple) schedules as a framework within which to investigate interactions between behaviors controlled simultaneously. Under a concurrent schedule two or more schedules are in effect at the same time; although they are formally independent of one another, it is often the case, as shown below, that consequences occurring under one schedule do have a substantial effect on performance under another. In these experiments we have concentrated on establishing performance maintained either by different events (food versus shock) or by different arrangements of the same event (shock postponement versus shock avoidance). The details of each of these studies are summarized below.

Development of behavior maintained by shock presentation

Progress in this experiment has been both substantial and beneficial. The experiment was initiated to answer several questions about the maintenance of responding by response-produced shock: is merely a history of shock postponement, even though with a different response, sufficient for the development and maintenance of responding by shock presentation? Is it possible to maintain simultaneously responding that both produces and postpones shock? What types of interactions can exist between such behaviors, given that they can be maintained? Once established, does the subsequent elimination of the avoidance schedule also decrease responding maintained by shock? As can be seen, these questions are fundamental to the overall objectives of the contract objectives and the progress towards answering them is given in the following pages.

Previous experiments in our laboratory (Barrett and Glowa, 1977;

Barrett and Spealman, 1978) and elsewhere (Byrd, 1969; McKearney, 1968; Morse and Kelleher, 1977) have shown unquestionably that a history of shock postponement is a sufficient (though not necessary) condition for the development of responding maintained by shock presentation (see Progress Report Number 1 and McKearney and Barrett, 1978, for a review). In all of these experiments, lever pressing was initially established under the shock-postponement schedule and then a conjoint schedule was arranged. Under the conjoint procedure, the avoidance schedule remained in effect and along with it an FI schedule of shock presentation was programmed. Ultimately the avoidance schedule was removed and the FI shock-presentation schedule alone maintained responding, apparently indefinitely.

The first phase of the study conducted under this contract also consisted of establishing responding under a shock-postponement (avoidance) schedule (Table 3, page 18, summarizes the sequence of procedural steps followed in this study) and number of sessions at each procedure. Rather than use the conventional lever, however, a chain was installed, suspended from the front top of the Plexiglas panel which faced the monkey. In the initial portion of this study a lever was also present and, although lever responses were recorded, they had no scheduled consequence. Not unexpectedly, steady rates of chain pulling occurred within 2-5 sessions and very few avoidance shocks were delivered. Few lever responses occurred once avoidance responding was established. The next step in the procedure consisted of placing an FI 3-minute shock-presentation schedule in effect for lever responses. Throughout this phase the avoidance schedule continued to operate (shock intensity was the same, 5 mA, for both schedules). Only a small number of responses were made on the lever during the time both schedules and manipulanda were in operation. Lever pressing did develop, however, when the chain <u>and</u> shock-postponement schedule were removed.

Figures 5 (page 19) and 6 (page 20) show initial performance under the concurrent chain-pulling (avoidance) lever-pressing (shock-presentation) schedule and the subsequent development of responding maintained by shock presentation. Shown in the top panel of these figures are the steady moderate rates of responding that occurred on the chain when both the avoidance and shock-presentation schedule were in effect; no responding occurred on the lever during this phase. In the second panel the chain and accompanying shock-postponement schedule were removed and responding then developed on the lever with both monkeys. For MS-47 (Figure 6, page 20) responding was slower to develop; schedule and chamber modifications were made that resulted in the occurrence of moderate and steady response rates (the chair modification referred to in the figure consisted only of placing a wall in the chair to reduce the amount of available space; this enhanced the likelihood of a lever press response and contact with the response-produced shock schedule). For both monkeys then, by the end of session 1, steady rates of responding were occurring when the only consequence was the presentation of electric shock. By session 6 (MS-46, Figure 5, page 19) or session 8 (MS-47, Figure 6, page 20) higher response rates were well-maintained, but no patterning was evident. Figure 6 also shows session 2 for MS-47; during this session the chair was not fitted with the artificial wall. The lower records in each figure show that after 35 (MS-46) or 43 (MS-47) sessions, positively accelerated patterns of responding occurred that were maintained solely by

TABLE 3

Sequence of conditions and number of sessions at each condition

Schedule	MS-46	MS-47
Avoidance (chain)	1-5	1-5
Conc Avoidance FI 3 (shock, lever)	6-12	6-12
FI 3	13-43	13-43
Conc Extinction (chain) FI 3	-	44-50
Avoidance	44-60	-
Conc Avoidance FI 3	-	51-73
FI 3	61-75	74-79
Conc Extinction (chain) FI 3	76-81	-
Conc Avoidance FI 3	82-85	80-132
FI 3	86-105	-
Conc Avoidance FI 3[a]	106-148	133-159
Avoidance	149-151	160-168
Conc Avoidance FI 3	152-155	169-181
FI 3	156-167	-
Conc Avoidance FI 3	168-171	-
Avoidance	172-178	-
Conc Avoidance FI 3[b]	179-222	182-226

[a] RS interval, or the length of time a response postpones shock, was increased from 25 to 45 seconds and shock intensity increased to 10 mA for both monkeys.

[b] Shock intensity changes from 1-10 mA, each in effect for about 15 sessions.

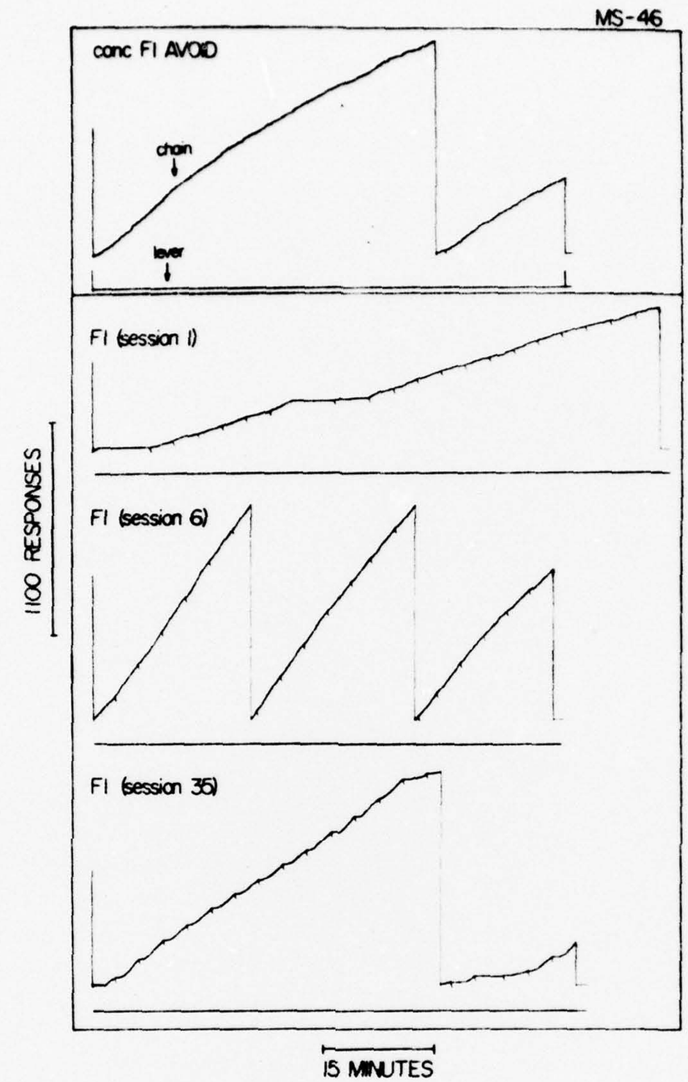

FIGURE 5

Cumulative records of MS-46 under the initial concurrent shock-avoidance (chain pull response) and shock-presentation (lever press) schedule (top panel). Immediately prior to session 1 the chain and accompanying avoidance schedule were removed and performance developed on the lever. Subsequent records show development of characteristic fixed-interval performance that occurred when only the lever was present and responding produced shock. Recording as in previous figures. Diagonal marks denote shock delivery. The pens returned to baseline when approximately 1100 responses had been made. See text for complete description.

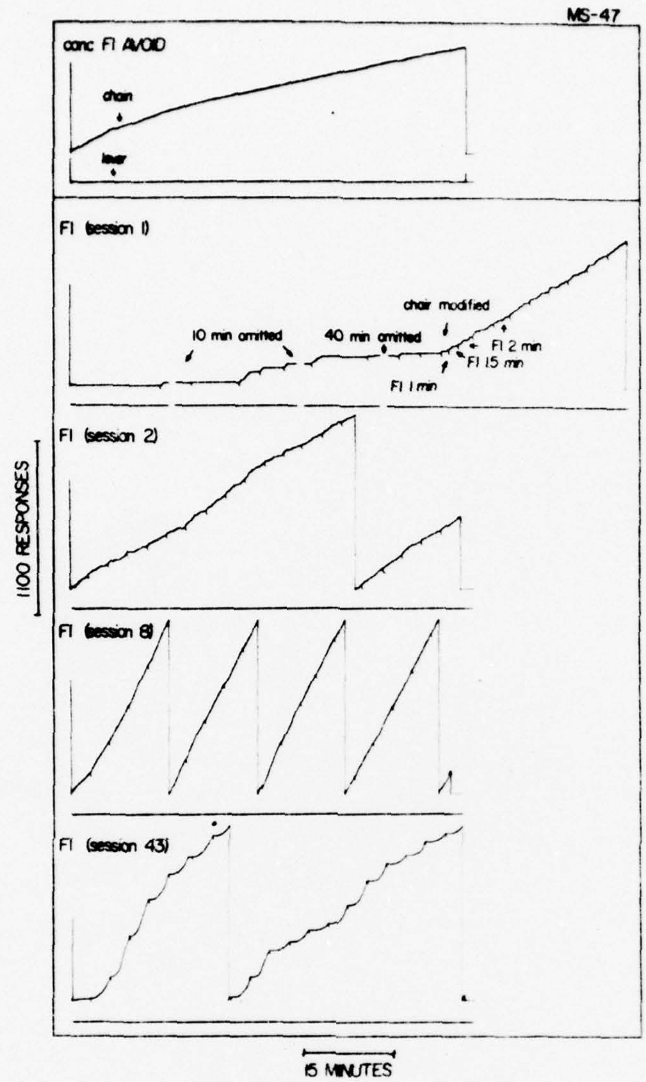

FIGURE 6

Cumulative records of MS-47 under the initial concurrent shock-avoidance (chain pull response) and shock-presentation (lever press) schedule (top panel). Immediately prior to session 1 the chain and accompanying avoidance schedule were removed and performance developed on the lever. Subsequent records show development of characteristic fixed-interval performance that occurred when only the lever was present and responding produced shock. Recording as in previous figures. Diagonal marks denote shock delivery. The pens returned to baseline when approximately 1100 responses had been made. See text for complete description.

response-produced electric shock. These patterns are identical to those maintained by food, stimulus-shock termination and a wide range of other events (see last year's Progress Report).

This portion of the study provided unequivocal evidence that a history of shock postponement, even though with a different response, was sufficient to allow performance to be maintained by the presentation of electric shock. In the next phases of the study (Table 3, page 18) the effects of reintroducing the shock-avoidance schedule were examined, as were changes in shock intensity and interactions between the two schedules.

Simultaneous maintenance of behavior by shock presentation and shock postponement

In Figures 7 (MS-46, page 22) and 8 (MS-47, page 23) the effects of reintroducing the chain are shown. The avoidance schedule was not placed in effect when the chain was first reintroduced. The records labeled Conc FI EXT show some disruptive effect on lever pressing maintained by shock upon introduction of the chain, even though the avoidance schedule was not operative. There was a gradual reduction of chain pulling over the course of the session and chain responses continued to occur at a low rate in subsequent sessions (see, e.g., session 104 for MS-46). Substantial disruption of lever pressing occurred when the avoidance schedule was placed in effect (Conc FI Avoid) and a large number of avoidance shocks occurred. Over the next series of sessions, with both avoidance and shock-presentation schedules in effect simultaneously, rates increased on the chain and performances maintained on the lever returned to those characteristic of previous performances under this schedule. The bottom records for each monkey depict typical performances maintained under the concurrent shock-postponement and shock-presentation schedules: steady rates of chain pulling occurred that postponed most scheduled shocks while, simultaneously, positively accelerated patterns of lever pressing were maintained that produced shocks every 3 minutes.

When the shock intensity controlling these performances was manipulated from 1-10 mA response rates on the lever changed more than those maintained by the chain and the avoidance schedule (Figure 9, page 24).

Figure 10 (page 25) illustrates interactions occurring between the performances controlled by the two schedules. When an avoidance shock occurred, it initiated a pause in lever pressing if lever pressing was occurring at the time an avoidance shock was delivered. Several of the fixed-intervals have the appearance of two "scallops," the first of which was created by the occurrence of an avoidance shock. Thus, even though the performances are distinct in their rate and temporal patterning, shocks delivered under the avoidance schedule clearly have an effect on both behaviors, initiating responding maintained by shock postponement and producing a pause in responding maintained under the FI shock-presentation schedule.

As mentioned in the introduction to this section, this study has provided a wealth of information on the development, maintenance and type of interactions under concurrent shock-presentation shock-postponement

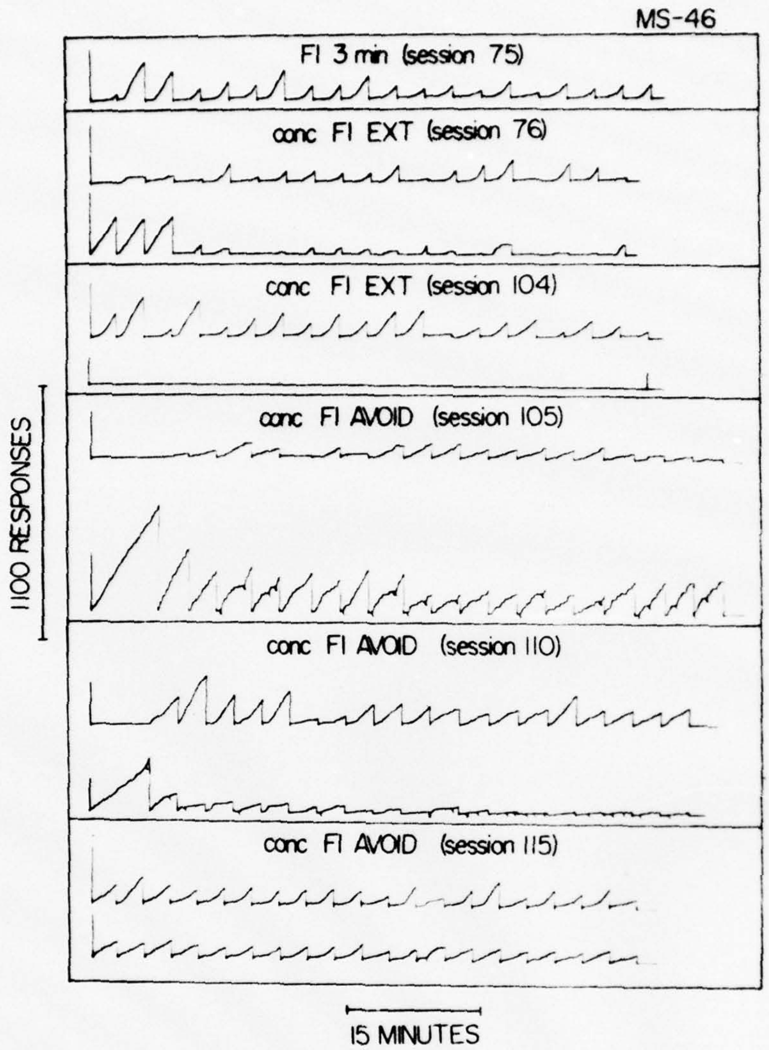

FIGURE 7

Cumulative records of performances under different schedules of shock presentation and concurrent shock presentation and shock postponement (MS-46). This figure shows the development and eventual maintenance of responding under a concurrent schedule where a chain-pulling response postponed or prevented shock while, simultaneously, a lever-pressing response produced the same shock. Each schedule maintained appropriate performances. Shocks are shown as diagonal slashes. The pens reset to baseline with the delivery of shock under the fixed-interval 3-minute schedule.

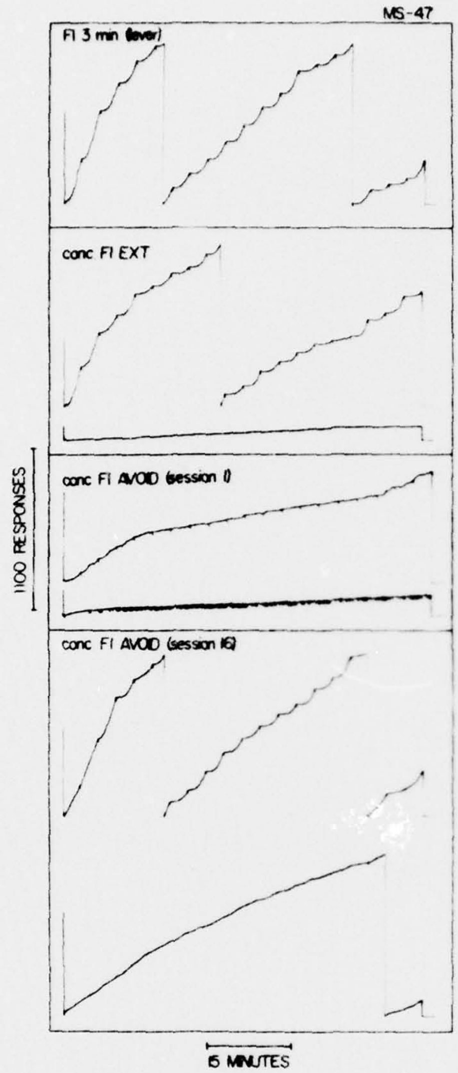

FIGURE 8

Cumulative records of performances under different schedules of shock presentation and concurrent shock presentation and shock postponement (MS-47). Shocks are shown as diagonal slashes. The pens reset to baseline with the delivery of shock under the fixed-interval 3-minute schedule.

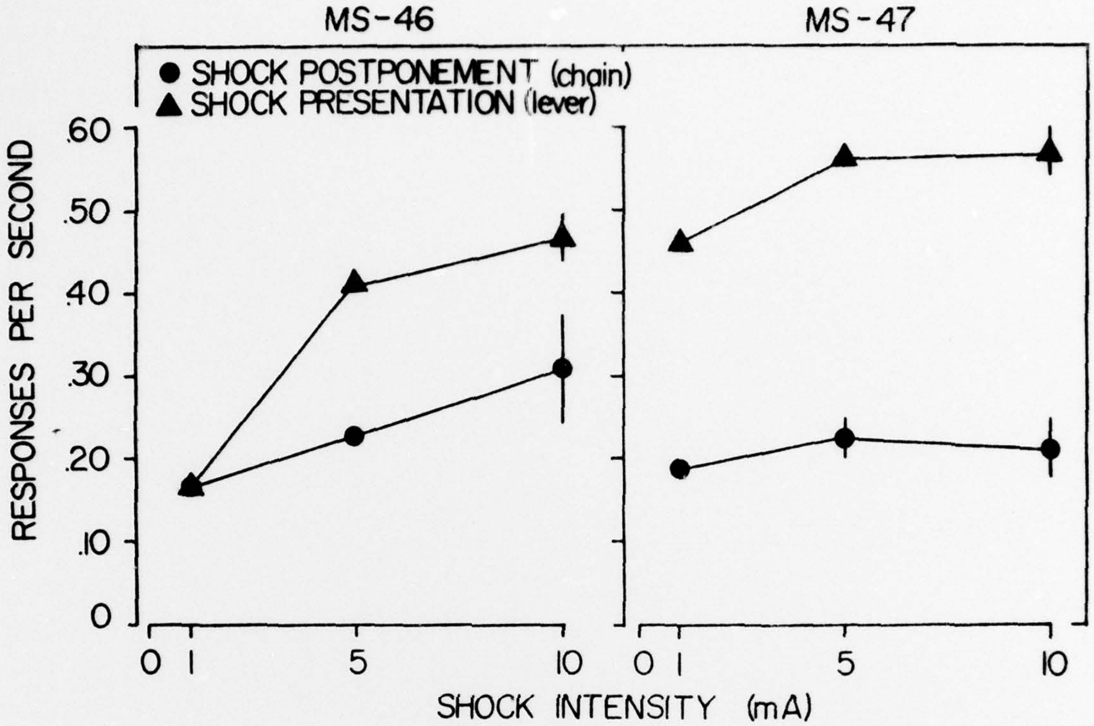

FIGURE 9

Effects of shock intensity changes on responding maintained under the concurrent shock-postponement, shock-presentation schedule. Vertical lines show range of values at redetermined points. Data are mean of last 3 sessions at each value.

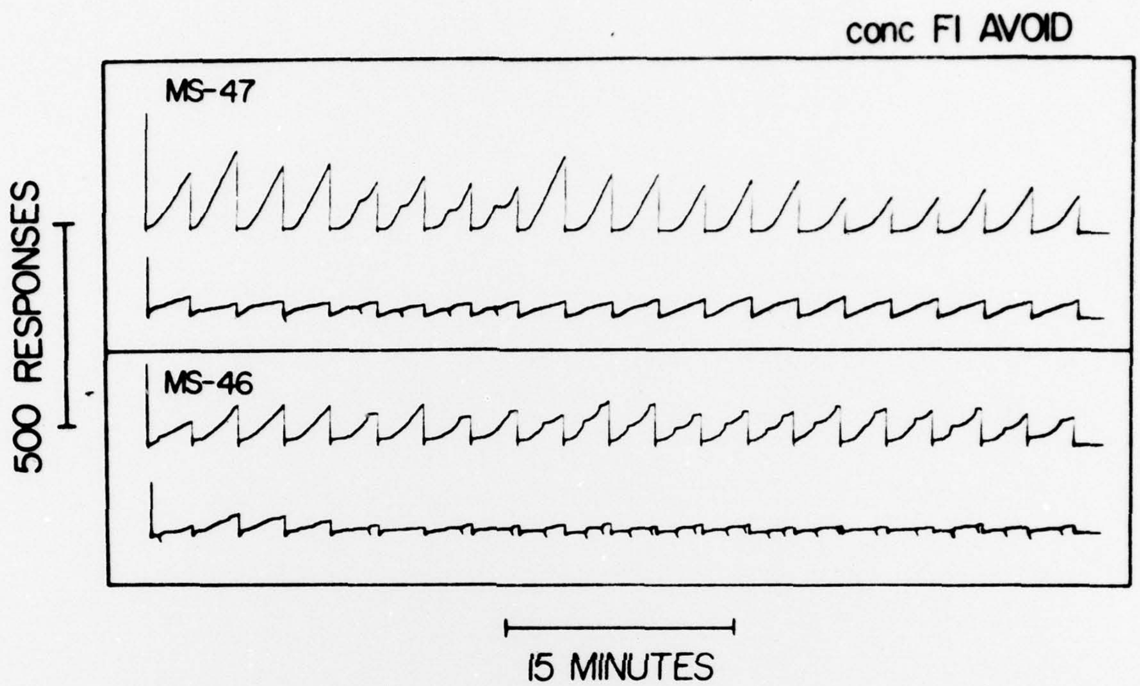

FIGURE 10

Cumulative response records showing interactions between performances maintained under the concurrent shock-presentation (top record in each pair) shock-postponement (lower record) schedule. Recording as in previous figures. Note the pauses in lever pressing that occurred when an avoidance shock was delivered.

schedules. First, a history of avoidance was all that was required for the development of a new response maintained by shock presentation. Monkeys in this study received initial training with a chain response that postponed shock; although a shock-presentation schedule was arranged for pressing the lever, lever pressing did not develop until the chain and accompanying avoidance schedule were removed, essentially forcing some contact with the lever and shock-presentation schedule. Once this occurred, however, lever pressing developed rapidly and has been maintained ever since. Significantly lever responding, maintained by shock, continued to occur even when the chain-pulling response was extinguished by removal of the shock-postponement schedule.

Secondly, performances maintained simultaneously by these two schedules were characteristic of those observed previously when studied in isolation. When shock occurred under the avoidance schedule, interactions were observed that were also in accord with that schedule and particular response. The two schedules appeared to have separate integrity, but were clearly subject to influences from one another. Further analyses of performances maintained under these conditions will be continued during the course of the next year and should further reveal dynamic interactions between performances simultaneously maintained by shock presentation and shock postponement.

<u>Simultaneous maintenance of behavior by food and shock presentation</u>

In this series of experiments we have first concentrated on the development of performances separately maintained either by food or shock presentation alone. A standard chair, with the potential for being equipped with two adjacent levers is used. During initial phases only one lever is present and responses on it produce food (right lever) or shock (left lever). After both responses have been separately developed, then the second lever along with the accompanying food or shock schedule is placed in effect simultaneously with the extant schedule.

The basic objective in these studies was to first develop behaviors that are occurring simultaneously and which are maintained by the different events of food or shock. Once established as concurrent schedules, the plan was to modify the consequences controlling performance under one of the schedules and determine the effects of this manipulation on performance under the unchanged schedule. Despite the relevance to behavior under naturally-occurring conditions, very little work has been performed on behaviors controlled under concurrent schedules where different reinforcing events are used (e.g., Hollard and Davison, 1971; Hursh, 1978; Miller, 1976).

During the past year we have been successful in establishing and maintaining lever pressing under concurrent VI schedules of food and electric shock presentation. Initially, it was considered important to attempt to equate response rates occurring on the separate levers. Therefore, several changes in shock intensity and shock frequency were made to reduce the normally higher response rates controlled by shock. In some cases these attempts were not successful. The interval values and shock intensities studied first were selected primarily on the basis of those yielding reasonably comparable rates under the two schedules.

The procedure for each monkey was generally similar and straightforward. Once lever responding was established under each schedule, both schedules were placed in effect, each controlled by separate VI schedules. The tapes controlling each VI arranged a constant-probability of food or shock (Catania and Reynolds, 1968). When the food magazine was operating (4-second cycle of liquid food), a shock could not be delivered.

Table 4 (page 28) summarizes the sequence of conditions to which three monkeys have been exposed thus far. For two monkeys (MS-53 and MS-60), the parameters of the shock schedule were held constant while the food schedule was varied from 90 seconds to 6 minutes. With the third monkey (MS-58) the VI shock schedule was changed over the same range while the food schedule remained at VI 90 seconds.

Figure 11 (page 29) shows a typical performance generated under the concurrent VI schedules of food and shock delivery (MS-53). Response rates are generally quite steady; little pausing occurred and at these parameter values for this monkey [VI 6-minute (food) VI 9-minute (shock)] response rates were quite comparable. Table 4 (page 28) also provides results obtained at each of the VI schedule values studied. Considering first the two monkeys for whom the shock schedule was constant and the food value changed (MS-53 and MS-60), there was some tendency for rates of responding maintained by food to decrease with increases in the VI from 90 seconds to 6 minutes. Rates on the shock lever changed inconsistently for the two monkeys: with MS-53 responding maintained by shock declined after the first schedule change and then remained low for the succeeding three phases. With MS-60, both shock- and food-maintained responding increased initially when the food schedule was changed from VI 90-second to VI 3-minute. Subsequently, with a change from VI 3-minute to VI 6-minute food, rates declined on both levers. A further decline in rates on the two levers occurred when the original concurrent VI 90-second (food) VI 6-minute (shock) schedule was again in effect for MS-60.

For MS-58, food maintained rates of responding changed little when the VI shock schedule was modified. Shock-maintained rates were systematically related to the value of the VI shock-presentation schedule: decreases in the VI from 6 minutes to 90 seconds produced a near three-fold increase in rates.

The data gathered thus far are unquestionably ambiguous and inconclusive. Further work is required over the next year to determine whether more orderly relationships exist between behaviors controlled in this manner. It is possible that performances maintained under these conditions are not terribly sensitive to manipulations of this type or that such orderly relationships may be obscured by other variables. Morse and Kelleher (1966, 1970) have suggested that performances maintained under shock-presentation schedules may be metastable. Such performances are characterized by two different stable rates or patterns of responding under the same schedule parameters before and after an intervening treatment. Insofar as the effects of a change in schedule conditions may depend upon the rates and patterns of responding existing at the time the change is made, this feature could play some role in determining the outcome. It should also be added, however, if

TABLE 4

Sequence of conditions and mean response rates at each condition[1]

SCHEDULE	RESPONSE RATE (Responses per second)	
	Food	Shock
MS-53		
VI 90-sec (food) VI 9-min (shock)	1.23	1.42
VI 3-min (food) VI 9-min (shock)	1.23	0.924
VI 6-min (food) VI 9-min (shock)	1.01	1.01
VI 90-sec (food) VI 9-min (shock)	1.27	0.975
MS-58		
VI 90-sec (food) VI 6-min (shock)	.330	.228
VI 90-sec (food) VI 90-sec (shock)	.314	.749
VI 90-sec (food) VI 3-min (shock)	.319	.658
VI 90-sec (food) VI 6-min (shock)	.298	.357
MS-60		
VI 90-sec (food) VI 6-min (shock)	1.07	1.26
VI 3-min (food) VI 6-min (shock)	1.27	1.73
VI 6-min (food) VI 6-min (shock)	.807	1.54
VI 90-sec (food) VI 6-min (shock)	.704	1.27

[1] Figures are the mean of the last 3 sessions. Shock intensity was 1.5 mA for MS-53 and MS-60 and was 3 mA for MS-58.

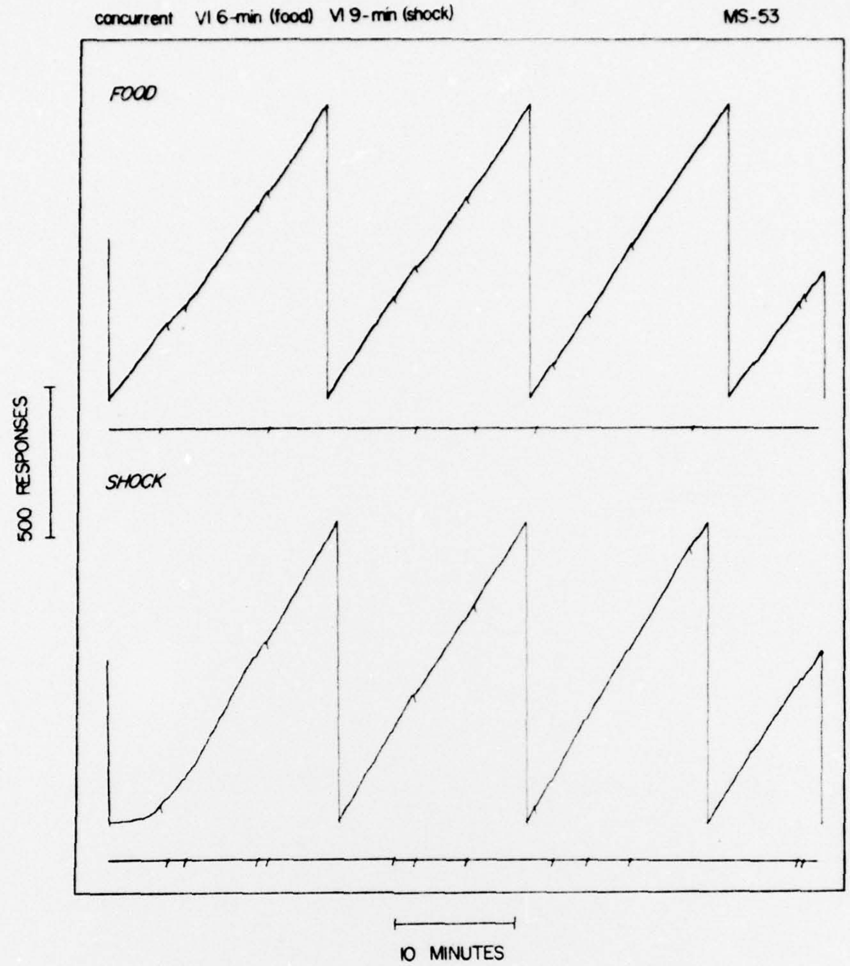

FIGURE 11

Cumulative response records of responding maintained under concurrent variable-interval 9-minute shock and 6-minute food-presentation schedules. Records of food performance are shown in the top record, those of shock in the lower record. Diagonal marks denote food or shock presentation.

metastability is a characteristic of behavior under these conditions, systematic relationships between controlling variables are less easily determined.

It may also be necessary to examine other procedural manipulations such as a changeover delay (COD) that would impose some minimum time between the delivery of shock or food and a response on the opposite lever. This might help to minimize interactions between the schedules and may prevent one response from coming under the control of the alternate maintaining event (Sidman, 1958). The pursuit of an answer to these questions and an eventual understanding of performances under these schedules comprises one of the main objectives during the next year of this project.

Second-order schedules of food and shock presentation

Throughout the past year we have concentrated primarily on schedule conditions where the maintaining event, either food or shock presentation, or stimulus-shock termination, occurs following each completion of a specified number of responses (ratio schedule) or after a period of time (interval schedule).

There are, however, distinct advantages to procedures which permit the development and analysis of extended sequences of behavior maintained only ultimately by the consequent event. Recent research in behavioral pharmacology has resulted in techniques that allow responding to be maintained by a single end-of-the session intramuscular drug administration (Goldberg, 1975; Kelleher, 1975); throughout the session, responding produces a stimulus correlated with the terminal drug injection. Termed a second-order schedule, these procedures provide a unique opportunity to experimentally study behaviors occurring over lengthy periods of time in the absence of recurring frequent reinforcing events. Situations like these are very directly analogous to those occurring under nonlaboratory conditions.

In one study initiated under this contract we attempted to determine whether comparable performances could be established under second-order food- and shock-presentation schedules. A schedule was arranged so that the first response after 3 minutes had elapsed produced a 2-second brief stimulus (a change in the chamber illumination from white to green). This schedule (termed the "unit" schedule) is a fixed interval. Initially only two FI's had to be completed before the stimulus was followed by food or shock [designated FR 2 (FI 3:S)]. Over the course of approximately two weeks the number of intervals required for food or shock was increased to 10; at least 30 minutes now elapsed from the initiation of responding to the delivery of the consequent event [FR 10 (FI 3:S)]. Performances maintained under this second-order schedule are strikingly impressive and comparable (see Figure 12, page 31). The brief stimulus presentation maintained orderly high rates of responding throughout the session in the absence of recurring presentations of either food or shock. Situations such as these are formally similar to circumstances where behavior only ultimately results in reinforcement and, during the interim, is maintained by correlated stimuli. The advantages to this project of developing

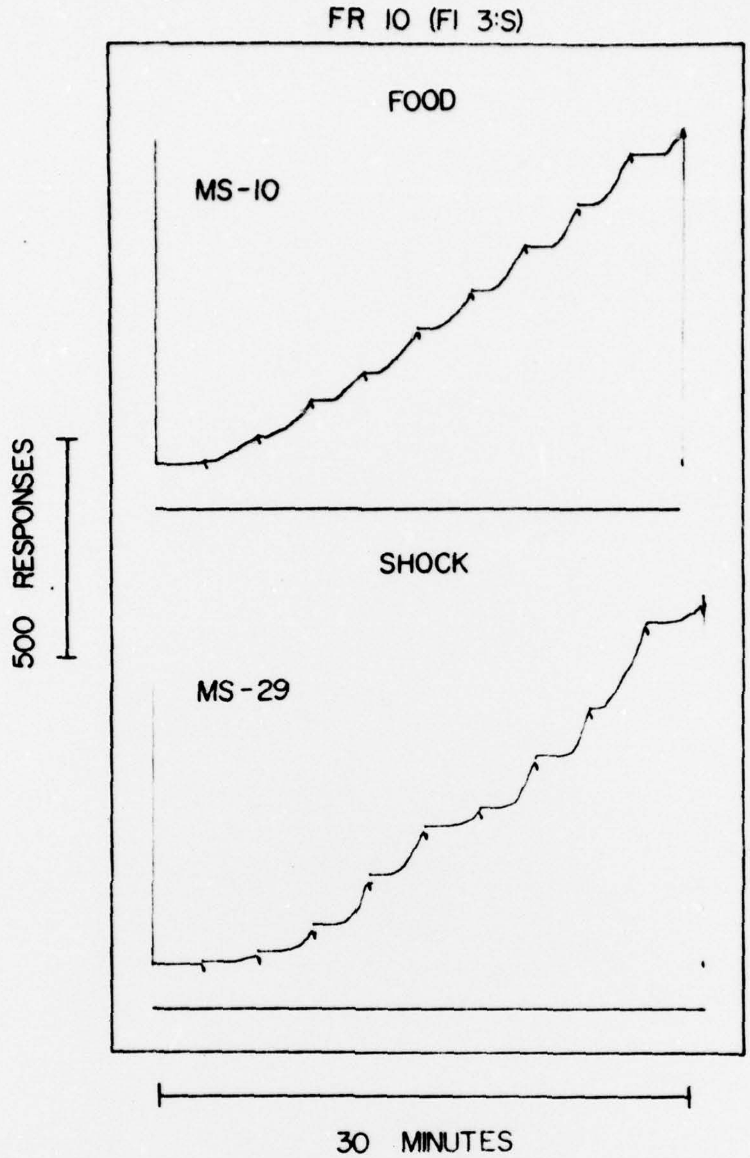

FIGURE 12

Cumulative records of performances under second-order schedules of food or shock presentation [FR 10 (FI 3-min:S)]. Under this schedule the first response after 3 minutes produced a 2-second brief stimulus (denoted by diagonal slashes on the records). Following completion of the tenth fixed-interval the brief stimulus was followed by food or by shock delivery. Note the comparable performances maintained by these two events.

protracted performances occurring over extensive time periods are many. When the maintaining event occurs only once, at the end of the session, there is less danger of direct interactions between that event and other variables of interest. Procedures of this kind also minimize potential problems of food-satiation, cumulative effects of shock, etc. Figure 13 (page 33) shows the effects on performance under a second-order shock-presentation schedule of increasing the number of shocks from 3 to 10 when these shocks occur only once, at the end of the session. This is only one of the many possible manipulations under schedules of this type.

The exploration and development of techniques such as these offer a further beneficial means of extending an interest in behavioral interactions under noxious environments to a wide range of situations. The continuation of these experiments during the forthcoming year should provide new information and should lend further generality to the findings emanating from the project.

Conclusions

The work conducted over the past year has focused on the analysis of performances sequentially and simultaneously controlled primarily by noxious consequences. Two areas of fundamental concern have been that of i) determining the nature and extent of interactions between behaviors under these conditions and, ii) an understanding of factors responsible for the development of performances maintained solely by the presentation of an otherwise noxious event. On the basis of findings obtained thus far several aspects are apparent. Extremely orderly performances can be developed and maintained with noxious stimuli. It has so often been stated that noxious events produce degraded performances and/or degenerative behavior that outcomes such as those summarized above are particularly striking. Remarkably stable, integrated and orderly performances were developed and maintained over a period of more than a year.

The same stimulus, electric shock, was seen to exert dramatically different effects on behavior depending on how it was scheduled, the organism's previous history, and on factors occurring elsewhere under different conditions. As described above, under some conditions the responding by subjects in this program was maintained simultaneously by the presentation of shock and by shock postponement. Under other conditions the same shock suppressed behavior when one stimulus was present and maintained performances when a different stimulus was present. It is impossible to argue that the behavioral properties of environmental events are immutable. The unfortunate tendency in the past has been to arbitrarily assume that the properties of consequent events were based on their hedonic value when, in fact, other more manipulatable environmental features are equally or perhaps even more important.

It is generally true that the specific effects that the consequences of behavior have are determined by a large number of complex factors. The results of this research should help in the development of a more appropriate

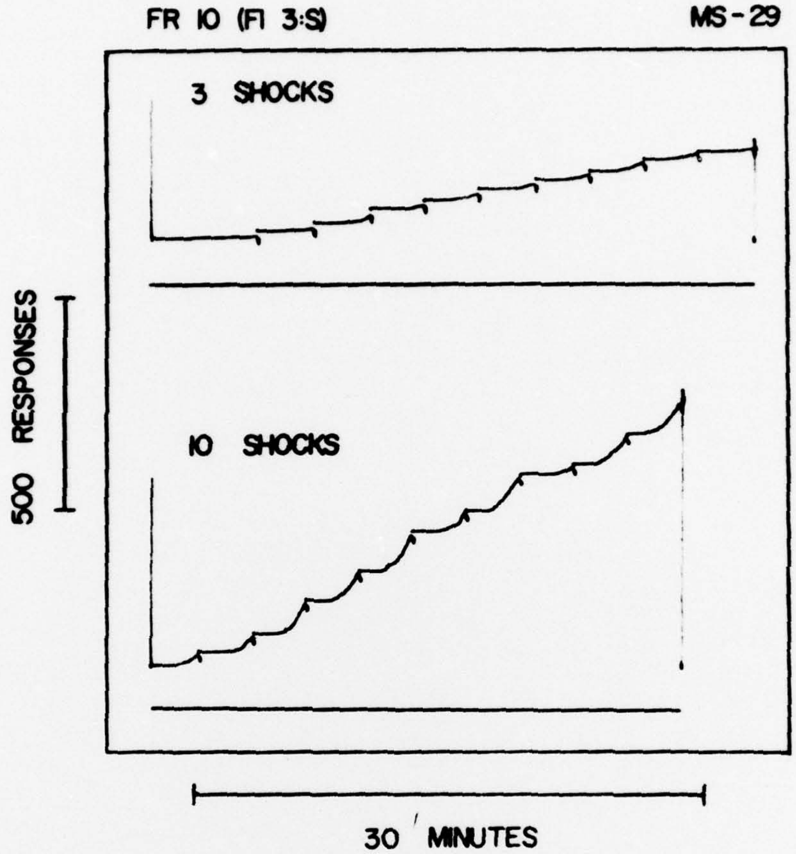

FIGURE 13

Effect of the number of shocks delivered under a second-order schedule where all shocks occur at the end of the experimental session. Response rates were higher and patterning more apparent when 10 rather than 3 shocks occurred.

perspective about the precise manner in which behavior is controlled by its consequences, particularly when those consequences are noxious. Continued progress and experimentation along the lines specified above should contribute substantially to our understanding of behavior under noxious environments and to the multiple ways in which behavior is affected under such conditions.

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