THE UNIVERSITY OF MANITOBA

CONDITIONED AND UNCONDITIONED SUPPRESSION OF FREE-OPERANT AVOIDANCE BEHAVIOR

BY

MARIAN A. WEISS

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE
STUDIES IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

OCTOBER, 1977

THE UNIVERSITY OF MANITOBA LIBRARIES

CONDITIONED AND UNCONDITIONED SUPPRESSION OF FREE-OPERANT AVOIDANCE BEHAVIOR

by

Marian Anne Weiss

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF ARTS

© 1977

Permission has been granted to the LIBRARY OF THE UNIVERSITY OF MANITOBA to lend or sell copies of this dissertation, to the NATIONAL LIBRARY OF CANADA to microfilm this dissertation and to lend or sell copies of the film, and UNIVERSITY MICROFILMS to publish an abstract of this dissertation.

The author reserves other publication rights, and neither the dissertation nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

TABLE OF CONTENTS

Page

REVIEW OF THE LITERATURE AND STATEMENT OF THE PROBLEM - 1

Operant and elicited responding in experiments on free-operant avoidance ---------- 7

Operant and elicited responding in experiments using the Estes-Skinner paradigm ---------- 11

METHOD ---------- 18

Subjects ---------- 18

Apparatus ---------- 18

Procedure ---------- 20

Recording of data ---------- 24

The suppression ratio ---------- 25

RESULTS ---------- 27

Suppression ratios ---------- 27

Avoidable shocks received per session ---------- 41

Post-shock response distributions ---------- 46

Summary of main findings ---------- 65

DISCUSSION ---------- 70

Overview ---------- 70

Measures of suppression ---------- 72

Unconditioned suppression to the clicker stimulus - 77

Effects of signal-shock pairings ---------- 82

Post-shock response distributions ---------- 86

Summary of main conclusions ---------- 91

REFERENCES ---------- 94

ABSTRACT

This study consisted of six phases in which four rats were exposed to a free-operant avoidance schedule during 2-hr daily sessions. The avoidance behavior was lever pressing. Lever bites as well as lever presses were recorded. During Phase 1, 30 one-minute clicker presentations (CPs) were superimposed on the free-operant avoidance baseline. White noise was presented during the other 90 minutes of each session. All rats showed suppression of avoidance during the clicker in that more shocks occurred during this stimulus than during its absence. There was little or no difference, however, in the number of lever presses in the presence and absence of the CPs. An analysis of response distributions indicated that many of the lever-press responses were due to shock-elicited lever attacking as well as to operantly conditioned avoidance behavior. During Phase 2, a 0.50 second unavoidable shock followed each CP, resulting in an increase in avoidable shocks throughout the session. However, the relative number of shocks and the relative number of lever presses in the presence and absence of CPs remained the same as in Phase 1.

During Phase 3, unavoidable shocks following CPs

were removed resulting in increased avoidance as measured by a decrease in avoidable shocks throughout the session. Similar to Phase 1 and 2, however, more shocks were received during CPs than during the absence of CPs while the lever-press measure of avoidance showed no such difference between the presence and absence of CPs.

In Phase 4, the temporal positions of the two auditory stimuli of the experiment were reversed; that is, white-noise presentations (WNPs) occurred in place of the CPs, so that 30 WNPs and 90 minutes of clicker noise occurred each session. Fewer shocks were received during WNPs than during equal session time during which the white noise was absent and the clicker noise was present. There was little or no difference in the relative number of lever presses in the presence and absence of WNPs.

In Phase 5, each WNP was followed by a 1.0 second unavoidable shock. This resulted in more avoidable shocks being received by one subject during WNPs than during other measured session time. The other three subjects, although showing an increase over Phase 4 in relative number of avoidable shocks received during WNPs, still received fewer shocks during WNPs than during equal session time during which white noise was absent and the clicker noise was present. As in Phase 2, the main effect of unavoidable shock presentations was impaired avoidance, indicated by an increase in avoidable shocks received by all rats, throughout the session.

In Phase 6 the unavoidable shock contingency was removed. Avoidance of shocks increased for three out of four subjects.

These results have the following implications for studies using signal-shock pairings (the Estes-Skinner procedure) on an avoidance baseline:

1. Rate of the avoidance response, the variable typically used in previous studies to measure suppression, may be an inadequate measure of suppression.

2. Topography of the avoidance response may permit confounding of measures of avoidance behavior. Shock-elicited respondents may have been included in the measure of operant responses, thereby spuriously increasing the response rate.

3. The presentation of response-independent stimuli (i.e., unpaired with unavoidable shock) can result in changes in behavior which may have been previously attributed to signal-shock pairing.

4. The effects of signal-shock pairings are not confined to the presence of the pre-shock signal but may occur throughout the session.

5. Interpretations of the Estes-Skinner procedure in terms of conditioned anxiety stemming from the presentation of unavoidable shock may be misleading.

ACKNOWLEDGEMENTS

I wish to express my gratitude to the members of my committee, Professor Walter Driedger and Dr. Robert Tait of the University of Manitoba, for their constructive criticism of the manuscript. Special thanks is extended to my chairman, Dr. Joseph Pear for first introducing me to psychology as a science and for guidance and encouragement in the present endeavor.

I also want to express appreciation to the laboratory community of P130: Brian Rector, Linda McLean, and Peter Kaiser, for their assistance with programming of equipment and running of the subjects, and for making "the lab" a nice place to be. Thanks are due to Ed Black and Michael Hemingway for my initial introduction to the lab.

Finally, I want to thank Phil Geiler and Michael Weiss -- Phil, for helping me make the graphs and providing love and support during the writing of this thesis, and Michael, for being a constant source of strength over the years.

LIST OF FIGURES

FIGURE		Page
1.	Suppression ratios for lever presses, bites, and avoidable shocks for all subjects over each phase of the experiment ----------	28
2.	Total avoidable shocks per session received by all subjects over each phase of the experiment ----------	42
3.	Post-shock lever-press and post-shock lever bite rate distributions before and during CPs for all subjects for Phase 1 ----------	47
4.	Post-shock lever-press and post-shock lever-bite rate distributions before and during CPs for subjects 125H, 130H, and 150H for Phase 2 ----------	50
5.	Post-shock lever-press and post-shock lever-bite rate distributions before and during CPs for subjects 125H, 130H, and 150H for Phase 3 ----------	53
6.	Post-shock lever-press and post-shock lever-bite rate distributions before and during WNPs for all subjects for Phase 4 ----------	56
7.	Post-shock lever-press and post-shock lever-bite rate distributions before and during WNPs for all subjects for Phase 5 ----------	59
8.	Post-shock lever-press and post-shock lever-bite rate distributions before and during WNPs for all subjects for Phase 6 ----------	62

LIST OF TABLES

TABLE		PAGE
1.	Summary of the Procedure and Number of Sessions in each Phase for each Subject -----	21

REVIEW OF THE LITERATURE AND STATEMENT OF THE PROBLEM

> Almost every strong aversive stimulus is preceded by a characteristic stimulus which may come to generate anxiety. Contingencies of this sort are arranged in the practical control of behavior, often in connection with punishment. Although the biological advantage of avoidance is obvious, the emotional pattern of anxiety appears to serve no useful purpose. It interferes with the normal behavior of the individual and may even disorganize avoidance behavior which would otherwise be effective in dealing with the circumstances.
>
> (Skinner, 1953, p. 178)

Estes and Skinner (1941) developed what has since become a standard paradigm used to measure behavioral disorganization purportedly due to "anxiety". In their experiment, 24 rats were exposed to a schedule of reinforcement now known as a fixed interval of 4 minutes. The operant response was lever pressing and the reinforcement was food. When the behavior generated by this schedule had stabilized,

a 3-minute, and later, a 5-minute, tone was presented twice during each hour session. The tone terminated with the presentation of an unavoidable shock. Neither the tone nor the shock produced an observable behavioral disturbance in the early stages of this first experiment. Subsequently, however, the frequency of lever pressing decreased during the tone. Estes and Skinner went beyond their observable data and wrote, "The principle result of the experiment was the conditioning of a state of anxiety to the tone, where the primary index was a reduction in the strength of the hunger-motivated lever-pressing behavior (p. 392)".

Theoretical problems are raised with the use of the word "anxiety" to describe the above procedure and its behavioral effects. Some researchers (Hunt and Brady, 1951) have explicitly postulated that conditioned suppression is caused by an internal state which they called a conditioned emotional response (CER). They used the Estes-Skinner paradigm (which became widely labelled the CER paradigm) to assess the effects of a wide variety of physiological interventions, such as the administration of drugs, on the hypothesized underlying emotional state (Brady and Hunt, 1955).

Terminological confusion has resulted from the use of the terms conditioned anxiety and CER to describe the procedure as well as the results (or the underlying state of the organism which is responsible for the results). Some workers in the field, (e.g., Davis, 1968) argue for

the use of the term "conditioned suppression" of behavior, rather than "CER" or conditioned anxiety". In the present paper the procedure of imposing a signal-shock sequence on ongoing operant behavior will be referred to as the Estes-Skinner paradigm, and the term "conditioned suppression" will be used to describe decreased responding in the presence of the signal.

To some researchers, the respondent components in the Estes-Skinner paradigm seem immediately obvious. The tone is considered as the conditioned stimulus (CS) and the shock as the unconditioned stimulus (US). Various autonomic respondents and involuntary skeletal movements elicited by shock become elicitable by the tone alone. Thus, some investigators (Kamin, 1965; Rescorla and Solomon, 1967), having studied the relation of conditioned suppression to classical conditioning, are confident that the measurement of the changes in ongoing operant behavior as a result of signal-shock pairing offers a sensitive technique for the analysis of Pavlovian conditioning. On the other hand, some feel this assumption is gratuitous; suppression of ongoing operant behavior is only indirect if peripheral respondents are given the status of direct effects, and there is at least doubt that they are direct effects (Black, 1971; Brady, Kelly, and Plumbee, 1969; Smith, 1967).

In the Estes-Skinner procedure there is usually no measurement of the reflex topography elicited by the signal

or the shock. Using the "stimulus substitution" view of Pavlovian conditioning (Konorski, 1967; Skinner, 1938) it is questionable whether the Estes-Skinner paradigm is a true example of classical conditioning. Smith (1967) has argued that cases of seeming classical conditioning might reasonably be interpreted as examples of discriminative stimulus control of skeletal operant behavior shaped by reinforcement contingencies inherent in the classical conditioning procedure.

Several explanatory mechanisms have been evolved to explain the phenomenon of conditioned suppression. Pavlovian conditioned freezing, defecation, urination, piloerection, and other autonomic and motor effects are observed to occur to the signal being used as the preaversive stimulus. Responses such as freezing are thought to be incompatible with rearing to the lever and pressing it. Thus, conditioned suppression has often been explained by an incompatible response hypothesis (Kamin, 1965). Unfortunately, no systematic measurements of actual incompatible responses covarying with suppression have been made. Moreover, it is questionable whether the elicited respondents are incompatible with bar-pressing, especially in view of the data from bite lever experiments which are presented later in this chapter.

Another possible explanation for conditioned suppression might be described as an incompatible motivation hypothesis. One of the original investigators (Estes, 1969,

p. 80) has suggested:

> a stimulus which has preceded a traumatic event, e.g. shock ... acquires the capacity of inhibiting the input of amplifier elements from sources associated with hunger, thirst and the like. If then, while the animal is performing an instrumental response for, say, food reward, this conditioned stimulus is presented, the facilitative drive input will be reduced and so also the probability or rate of the instrumental response.

Thus, the motivational force of anxiety is said to reduce positive motivation for reinforcement and thereby decreases the frequency of operant behavior.

For some time motivational theories gained support because of their apparent ability to handle data describing the suppressive effects of signal-shock pairings on positively reinforced behavior such as lever-pressing as well as the apparent facilitative effects of signal-shock pairings on avoidance behavior. Early data (e.g. Sidman, Herrnstein, and Conrad, 1957) supported the assumption that aversively motivated operant behavior will increase in frequency during a stimulus which precedes an unavoidable shock, since the conditioned emotional state will summate with the motivation maintaining avoidance behavior (Rescorla and Solomon, 1967).

A more complex interpretation was suggested, however, when Azrin and Hake (1969) reported that responding maintained by food or water was suppressed in the presence of a relatively brief stimulus that preceded response independent presentation of food, water, or brain stimulation. These results have been supported by Meltzer and Brahlek (1970) and by Miczek and Grossman (1971). Moreover, in these and subsequent studies, the variables shown to be effective in determining the degree of response reduction in the presence of preshock stimuli also exert similar response suppression and, in some cases, facilitation, when prefood stimuli are used (Smith, 1974). In addition, it seems that the reports of increased avoidance responding during a preshock stimulus in avoidance experiments may have been due to the confounding of response measures. This confounding of response measures will be discussed in the following sections.

Despite three and a half decades of research on conditioned suppression, in which the findings of Estes and Skinner (1941) have been extended and replicated (see reviews by Lyon, 1968; Davis, 1968), as well as qualified as depending on the baseline schedule (e.g. Blackman, 1968), there is difficulty in forming an adequate theoretical explanation for the phenomenon. One difficulty results from conflicting data obtained in experiments on conditioned suppression when the Estes-Skinner paradigm is imposed on an avoidance baseline. As it is necessary to know the

properties of a baseline before one can assess the effects of an experimental operation on that baseline, a brief review of the relevant experiments on avoidance and some of the problems encountered in avoidance experiments is appropriate here.

Operant and elicited responding in experiments on free-operant avoidance.

The free-operant avoidance procedure consists of presenting the subject in an experimental chamber with brief inescapable shocks at regular intervals (the S-S interval; e.g., every 5 seconds). Although the subject cannot escape individual shocks, it can respond (e.g., by pressing a lever) to postpone the next shock for a certain period (the R-S interval; e.g., 20 seconds). If the subject responds at least once during that period (e.g., every 20 seconds), it will avoid all shocks. Using this procedure, Sidman (1958) computed response probability as a function of the length of pause since the last response. He found that response probability increased markedly as the time for shock approached. It was also very high immediately following shock; that is, shocks were observed to initiate rapid bursts of responding. Keller (1941) also reported response bursts in his early studies of light aversion in the white rat. Sidman accounted for post-shock response bursting by postulating that bursts occur through generalization from the "danger period", just prior to shock, to the "safe

period" that followed shock. Boren (1961) proposed a similar explanation for the response bursting he observed in a combined escape-avoidance paradigm, by stating that "immediately after the termination of an aversive stimulus the animal behaves as if the stimulus were momentarily still present (p. 266)."

Bursts of responses in rats, initiated during or after shock delivery, were reported by Malott, Sidley, and Schoenfeld (1963) under conditions of escape and avoidance, espace only, avoidance only, and an extinction condition in which all scheduled shocks were delivered irrespective of responding. Little systematic effect was found upon the response rate or upon the overall shock rate in the various phases of the experiment. That is, the pattern of responding in all four conditions was similar.

The possibility that response bursts may be accounted for by shock-elicited lever attacking was introduced with studies of reflexive fighting (Ulrich and Azrin, 1962; Ulrich and Craine, 1964; Ulrich, 1966). In these studies, fighting was elicited between paired rats as a reaction to electric shock prior to any specific conditioning. Other studies (Azrin, Rubin, and Hutchinson, 1968; Hutchinson, Azrin, and Hake, 1966; Azrin, Hutchinson, and Sallery, 1964; Azrin, Hutchinson, and Hake, 1967) found that subjects not only attacked each other in response to aversive stimulation but attacked inanimate objects. Azrin et al. (1968) reported shock-elicited biting attacks

towards wood, rubber, and metal targets by rats. Azrin et al. (1967) found that an avoidance response was learned with unusual rapidity when it had the same topography as elicited attack behavior (i.e., biting a rubber tube). The authors stated: "The attack reaction has probably been an undetected factor in the previous studies of avoidance and escape. For example, we have often noted that a rat or a monkey will bite a projecting object in the experimental enclosure during the initial stages of shock-avoidance conditioning (Azrin et al., 1967, p. 144)." They conclude that both attack and escape tendencies should be considered in studies using aversive stimulation.

Powell and Peck (1969) studied a negative reinforcement paradigm in which rats responded to reduce the intensity of the shocks delivered. They reported that some of the responses during post-shock bursting were biting attacks on the lever. Powell (1972) found an extreme persistence of responding when shocks were delivered independent of the subjects' responses during the extinction of avoidance behavior. He inferred that this continued responding during extinction was an effect of shock-elicited lever attacking.

The possibility that elicited aggression towards the operandum may account for some of the data obtained in studies of free-operant avoidance behavior was studied quantitatively by Pear, Moody, and Persinger (1972). They designed a lever which consisted of two parallel metal

plates, which, when pushed together, recorded a "bite". Depressions of the lever recorded "presses", as in standard lever-press experiments. Rats were placed on a free-operant avoidance schedule for lever pressing and then on extinction during which shocks were delivered independently of the subjects' responding. During both avoidance and extinction, post-shock lever biting was obtained. Since lever biting occurred independent of the avoidance schedule, the authors suggested that this attacking was shock-elicited and might account for many lever presses that previously were classified as operant behavior, such as post-shock response bursting (Sidman, 1958) and the persistence of responding during extinction when unavoidable shocks are presented (Powell, 1972).

A later study (Pear and Hemingway, 1973) recorded the temporal distribution of lever bites and lever presses during free operant avoidance. Rates of lever pressing and biting were much higher during the first two seconds after shock than during later intervals. The results support the suggestion (Pear et al., 1972; Powell, 1972) that post-shock bursting is due, in part, to shock-elicited attacks on the operandum.

A study by McLean (1975), in which rats avoided shock by pressing one lever and terminated shock by pressing another lever, used the bite lever designed by Pear et al., (1972). McLean found that post-shock lever-press bursting occurred only with those subjects that exhibited post-shock bursts of biting. The correlation between

bursts of lever-pressing and lever-attacking indicates that lever-press bursting is at least partially attributable to attacks on the lever. She concluded: "The contribution of elicited operandum attacking to post-shock bursting is indicative of the respondent component in post-shock bursts of responding. This type of elicited behavior may, in past research, have confounded measures of operant escape or avoidance responses (p. 74)."

The present study concerns itself with whether elicited behavior, in the form of bursts of lever-pressing and lever-biting, may have confounded measures of response suppression and facilitation in experiments using the Estes-Skinner paradigm on an avoidance baseline. The next section, therefore, describes conflicting results which have been obtained in experiments using the Estes-Skinner procedure on an avoidance baseline.

Operant and elicited responding in experiments using the Estes-Skinner paradigm.

As was mentioned earlier, one effect of pairing a stimulus with an aversive electric shock is the subsequent suppression of ongoing positively reinforced behavior during the pre-shock stimulus (Estes and Skinner, 1941). When signalled response-independent shock is superimposed on free-operant avoidance behavior, however, increased responding or conditioned facilitation is often reported during the pre-shock signal. For example, Sidman,

Herrnstein, and Conrad (1967) found increased responding during pre-shock signals with monkeys in a lever-pressing situation, and Rescorla and LoLordo (1965) found similar results with dogs in a shuttlebox. Increased lever-pressing during the signal has also been reported when a signal followed by unavoidable shock was super-imposed on an avoidance component of a multiple schedule for monkeys (Belleville, Rohles, Grunzke, and Clark, 1963) and dogs (Waller and Waller, 1963).

In the above-mentioned studies, the dependent variable was the rate of responding (e.g., rate of lever pressing) and it was measured with the assumption (at least implicitly) that, in the free-operant avoidance situation there is a direct correlation between rate of response and avoidance behavior. Hurwitz and Bounds (1968) challenged this assumption by demonstrating that the recorded rate of response may increase even though the number of shocks avoided may not increase or may actually decrease. Specifically, avoidance responses (i.e., responses that actually function to avoid shocks) may not increase during the pre-shock signal even though overall response rate during the signal does. The authors suggested that response bursts, elicited by unavoided shocks, may have increased the overall response rate during the signalled periods. Such bursts, however, do not constitute effective avoidance responses on a free-operant avoidance schedule because they occur immediately after shock.

Thus, there are two different, and at times conflicting, measures of avoidance in conditioned suppression studies: (1) number of responses (response rate) during a pre-shock signal compared to number of responses in the absence of the signal, and (2) number of avoidable shocks received during a pre-shock signal compared to shocks received in the absence of the signal. When effectiveness of avoidance was measured by counting relative frequencies of avoidable shocks received by subjects in the presence and absence of a pre-shock signal, impaired avoidance or conditioned suppression of avoidance behavior was reported (Bryant, 1972; Hurwitz and Roberts, 1971; Riess, 1971; Roberts and Hurwitz, 1970). Moreover, conditioned suppression of avoidance behavior, as measured by an increase in avoidable shocks during a pre-shock signal, was, under some conditions, correlated with an increased rate, or conditioned facilitation, of the lever-press response (Hurwitz and Roberts, 1971).

Several procedural differences in the studies using the Estes-Skinner paradigm on an avoidance baseline complicate a resolution of the conflicting data. First, as indicated above, the measures used to assess the effects of signal-shock pairing seem of critical importance. Impaired avoidance behavior during the signal was most clear when the consequences of an operant avoidance response rate were examined by comparing shock frequencies rather than lever-pressing in signalled and unsignalled periods. The lever-

pressing response measure was found to be unreliable because response bursts elicited by unavoided shocks during the signal often inflated the response rate value (Roberts and Hurwitz, 1970). Second, the intensity of avoidable shocks seems to be an important parameter determining whether suppression is obtained. With some strains of rats shock intensities greater than 1.4 mA may elicit response bursts which confound the lever-press suppression measure. Third, the length of the pre-shock signal is important. Roberts and Hurwitz (1970) found that five of their nine subjects responded at a relatively high rate to the onset of a one-minute preshock signal, although total rate of responding during the pre-shock signal was lower than response rate during the avoidance baseline. Conditioned suppression of the lever-press response was reported. If they had used a signal of short duration, however, their results might have indicated enhanced responding during the pre-shock signal. Rescorla and LoLordo (1965) and Grossen and Bolles (1968) both reported an increase in avoidance responding in terms of rate of response in the presence of a signal of 5 seconds duration.

Roberts and Hurwitz (1970) removed the free-operant avoidance schedule during the signalled periods in order to eliminate the confounding effects of response bursts following unavoided shocks. This control procedure introduces a different source of confounding: the "pre-aversive" signal indicates a time-out from the avoidance contingency. The

experimenters tried to control for this by presenting a signal which was not followed by unavoidable shock, but which also signalled time-out from avoidance, during later phases of the experiment. During all signalled periods, they found a reduction in response rate.

Hurwitz and Roberts (1971) attempted to re-examine the relationship between response rate and shock avoidance under the Estes-Skinner paradigm. They did this by measuring response rate and number of shocks received during a one-minute pre-shock signal, and during the one minute period before the signal. They found that subjects trained under low shock intensity (0.8 mA) showed reduced response rates and subjects trained under high shock intensity (2.0 mA) showed increased response rates during signalled periids. All subjects received more avoidable shocks as a result of signal-shock pairing, with the increase greatest during signalled periods. The increased response rate under the high shock-intensity condition may have been due to bursts of biting and pressing occurring after the unavoided shocks, although there was no measure to support this assumption.

It seems that the nature of the response during the signal must be looked at more closely before any satisfactory explanation of the behavioral effects of signal-shock pairing in the Estes-Skinner paradigm can be formulated. Present theories of response suppression will remain inadequate, unless the operant and respondent components of the

behavior are more clearly specified and measured. To accomplish this, it is not enough to consider only the consequence of the behavior, as is traditionally done. The topography of the response must also be examined.

The original purpose of the present study was to replicate the Hurwitz and Roberts (1971) study, with certain procedural variations designed to measure both topographies and consequences of responses. While Hurwitz and Roberts had three unavoidable shock intensities, the present experiment used only the high intensity level (2.0 mA). At this level Hurwitz and Roberts found both an increase in responding and, in terms of number of shocks avoided, suppression of avoidance in the presence of the signal. The present study sought to replicate this increase in responding and to examine it using a lever which measured lever bites as well as lever presses.

In the course of collecting these data, however, results emerged in the first phase of the experiment which warranted further investigation. These results concerned substantial changes in rates of response on an avoidance baseline during presentations of the stimulus that was later to be used as the signal. Since this stimulus was <u>not</u> followed by shock, the disruption in avoidance behavior during its presentation was not attributable to the signal-shock pairing procedure. Because of these initial results, several phases of the experiment were designed to compare the effects of two different auditory stimuli on the

avoidance behavior and shock-elicited lever biting.

The present experiment, therefore, examined effects of presenting an auditory signal alone, as well as effects of signal-shock pairings, on the relative number of avoidable shocks, the relative amount of lever-press responding, and the relative amount of shock-elicited biting attacks on the lever during the signal. The temporal distributions of these shocks, presses, and bites were also examined.

METHOD

Subjects.

Four experimentally naive, male, Long Evans hooded rats, bred at the University of Manitoba, served. The rats, which are hereafter referred to as 125H, 130H, 150H, and 154H, were about one hundred days old at the start of the experiment and their weights ranged from 450 to 550 gms. Except for two hours a day during which they were in the experimental chamber, the subjects were housed in individual cages in a temperature controlled room with a daily light/dark cycle of 13 hours light and 11 hours darkness. Food and water were available in the home cages at all times.

Apparatus.

The experimental space consisted of a dual lever test chamber 9 in. long by 8 in. high by 11.5 in. wide (23 x 20 x 29.2 cm) mounted in a Grason Stadler Research Chest, Model 1101. The chamber contained two bite levers of the type described and illustrated by Pear et. al. (1972). The levers were specifically designed to record both bites and presses. Downward pressure of more than 20 grams (.20N) activated a microswitch registering lever

presses, and simultaneous pressure exerted on the top and bottom of the lever of more than 250 grams (2.45N) activated another microswitch registering lever bites.

Protruding 0.8 in. (2.0 cm) into the chamber from the same 11.5 in. wall, separated by a distance of 1.6 in. (4.1 cm) measured from their inner edges, and located 3.3 in. (8.4 cm) above a grid floor, the levers were each 2.0 in. (5.1 cm) wide, 0.5 in. (1.3 cm) thick, and located 2.9 in. (7.4 cm) from the closer side wall as measured from the outer edge of the lever. They were constructed from 2024-T4 structural aluminum alloy, a metal that has been shown to hold up quite well to numerous biting attacks by rats. Only the lever closest to the inside wall was operative.

Electric shocks were delivered to the grid floor by means of a Grason Stadler shock generator and scrambler (Model #E1064GS). Illumination throughout all sessions was provided by a white, 7.5-W jewel lamp located above and midway between the two levers. Ventilation and a partial masking noise were provided by a fan in the sound insulated cubicle housing the experimental chamber. An additional masking noise ("white noise" at 84 db) and noise consisting of 30 clicks per second (86 db) were provided by a BRS-Foringer Model AV-901 audio generator. When the clicking noise was generated, the white noise stopped for the duration of the clicker. Standard relay-operated programming and recording equipment and a Gerbrand's cumulative recorder were located in a room adjacent to the room containing the experimental chamber.

Procedure.

Sessions were conducted for 120 minutes, scheduled at the same time daily, six or seven days per week for all rats. There was one three-day period during which sessions were interrupted. Throughout all phases of the experiment the rats were on a free-operant avoidance schedule (Sidman, 1953) in which the response-shock interval was 20 sec, (RS = 20 sec) and the shock-shock interval was 10 sec, (SS = 10 sec). That is, a 0.5 sec, 2 mA shock was delivered every 10 sec (the SS interval) unless a lever press occurred, in which case the shock would be postponed for 20 sec (the RS interval).

Subjects 130H, 150H, and 125H, were exposed to each of the six phases of the experiment in the sequence described below. On the basis of the results obtained during the first phase of the experiment subject 154H went directly from Phase 1 to Phase 4. A summary of the procedure and the number of sessions in each phase for each subject is shown in Table 1.

Phase 1 -- Free-operant avoidance schedule with one-minute clicker presentations. A one-minute stimulus consisting of 30 clicks per second was superimposed on the standard avoidance schedule 30 times during each 120 minute session. The white noise was interrupted during the clicker presentations (CPs). CPs were presented by means of a variable tape which was programmed to activate the clicking

TABLE 1

Summary of the Procedure and Number of Sessions in each Phase for each Subject

Phase	Number of Sessions in each Phase and Session Numbers			
	125H	130H	150H	154H
1. Free-operant avoidance with CPs *	68 Sessions 1-68	68 Sessions 1-68	28 Sessions 1-28	76 Sessions 1-76
2. Free-operant avoidance with .5 sec shock following CPs	24 Sessions 69-92	24 Sessions 69-92	60 Sessions 29-88	
3. Free-operant avoidance with CPs (same as Phase 1)	28 Sessions 93-120	24 Sessions 93-116	20 Sessions 89-108	
4. Free-operant avoidance with WNPs **	20 Sessions 121-140	24 Sessions 117-140	24 Sessions 109-132	28 Sessions 77-104
5. Free-operant avoidance with 1.0 sec shock following WNPs	40 Sessions 141-180	40 Sessions 141-180	28 Sessions 133-160	52 Sessions 105-156
6. Free-operant avoidance with WNPs (same as Phase 4)	20 Sessions 181-200	20 Sessions 181-200	16 Sessions 161-176	8 Sessions 157-164

* CPs - 30 one min clicker presentations and 90 min white noise

** WNPs - 30 one min white noise presentations and 90 min clicker

sound for one minute out of every 4 minutes. The time between each CP varied from 2 minutes to 4 minutes. The sequence of CPs was repeated one-and-a-half times in a two-hour session and each session was started at a randomly chosen point in the sequence. Thus, out of the total session time, there were 90 minutes of white noise and 30 minutes of CP with a mean of 3 minutes of white noise occurring between each one-minute CP. The number of sessions in Phase 1 were 68, 68, 28, and 76 for subjects 125H, 130H, 150H, and 154H, respectively.

Phase 2 -- Free-operant avoidance schedule with unavoidable shock following clicker presentations. Coinciding with the termination of each 1-minute CP, a 2 mA, 0.5 second unavoidable shock was presented. (Thus, the unavoidable shock had an intensity and duration corresponding to that used in the free-operant avoidance schedule). Subjects 125H, 130H, and 150H were exposed to these contingencies for 24, 24, and 60 sessions, respectively.

Phase 3 -- Free-operant avoidance schedule with one-minute clicker presentations. This phase consisted of a reversal to the conditions described in Phase 1. That is, no unavoidable shocks occurred during this phase. Subjects 125H, 130H, and 150H were given 28, 24, and 20 sessions, respectively.

Phase 4 -- Free-operant avoidance schedule with one-minute white noise presentations. White-noise presentations (WNPs) were given during the 30 one-minute periods in which

CPs had been presented in the previous phases, and, conversely the clicker was presented during the 90 minutes during which the white noise had been presented. To facilitate communication, the abbreviations CP and WNP will refer exclusively to the conditions during which the clicker (Phase 1 - 3) or the white noise (Phase 4 - 6) were presented for 30 one-minute periods during a 120-minute session. When the clicker or the white noise consists of 90 minutes of a session, they will not be abbreviated. The sequence of WNPs was the same as the sequence of one minute CPs used in previous phases. Thus, out of the total session time, there were 90 minutes of the clicker noise and 30 minutes of WNPs, with a mean of 3 minutes of clicker occurring between each one-minute WNP. The clicker noise was off during occurrence of the white noise. The number of sessions given 125H, 130H, 150H and 154H were 20, 24, 24, and 28, respectively.

Phase 5 -- Free-operant avoidance schedule with unavoidable shock following one minute white noise presentations. Coinciding with the termination of each one-minute WNP, a 2 mA, 1.0 second unavoidable shock was presented. The unavoidable shock was of the same intensity as the avoidable shocks, but of a longer duration. The difference between the duration used here (1.0 second) and that of Phase 2 (0.5 second) was suggested by the fact that little change in some measures of behavior was observed at the lower shock duration. Subjects 125H, 130H, 150H, and

154H were exposed to these contingencies for 40, 40, 28, and 52 sessions, respectively.

Phase 6 -- Free-operant avoidance schedule with one-minute white noise presentations. This phase consisted of a return to the conditions of Phase 4. Subjects 125H, 130H, 150H and 154H were exposed to these contingencies for 20, 20, 16, and 8 sessions, respectively.

Recording of data.

The effects of the foregoing procedure were assessed by comparing several response measures obtained during the 30 CPs of Phases 1 - 3 and the 30 WNPs of Phases 4 - 6 with the response measures obtained during 30 one-minute periods of session time before these presentations. Thus, data were obtained from 60 minutes out of total session time, with total response measures from 30 minutes of session time before CPs (Phases 1 - 3) or WNPs (Phases 4 - 6) recorded separately from the response measures obtained from 30 minutes during CPs (Phases 1 - 3) or WNPs (Phases 4- 6).

There were always at least two minutes of session time between each CP or WNP, so that any local disruptive effect for one minute following the avoidable shock was not recorded in the data before the next CP or WNP signalling unavoidable shock.

The data recorded from each 30 minutes of session time (that is, before the CPs of Phases 1 - 3 and the WNPs

of Phases 4 - 6, and during CPs of Phases 1 - 3 and WNPs of Phases 4 - 6) were:

i) the number of avoidable shocks received by the subject

ii) total number of lever presses

iii) rates of lever presses during 10 discrete time intervals of 2 seconds following avoidable shocks and in the interval extending beyond 20 seconds following each shock

iv) total number of lever bites

v) rates of lever bites during 5 discrete time intervals of 2 seconds following each avoidable shock, and in the interval extending beyond 10 seconds following each shock

vi) lever presses occurring simultaneously with avoidable shocks

vii) lever bites occurring simultaneously with avoidable shocks.

In addition, the total number of avoidable shocks received during each 120 minute session was recorded.

The suppression ratio.

A widely used measurement in this area of research is the suppression ratio, which is a comparison between response rates during a stimulus and in its absence. Unfortunately, there has been no general agreement about the

best way to make this calculation (Blackman, 1976). The present study calculated suppression ratios using the formula B/ (A + B) (Kamen, 1965), where

B = frequency during the 60-second CPs or WNPs, and

A = frequency during the 60-second control periods before CPs or WNPs.

This results in a value of 0 for complete suppression , 0.50 for no suppression, from 0.50 to 1.00 for increased responding during the signal. That is, for the lever pressing measure, a ratio of 0 indicates complete suppression of bar pressing during a specified period (CPs in Phases 1 - 3 and WNPs in Phases 4 - 6), a suppression ratio of 0.50 indicates no suppression or no change in lever pressing rate during CPs or WNPs as compared to lever pressing in session time prior to CPs or WNPs, and a suppression ratio greater than 0.50 indicates an acceleration of responding during the specified period.

Suppression ratios for each session were calculated for the avoidable shocks received, for lever bites, and for lever presses emitted by each subject.

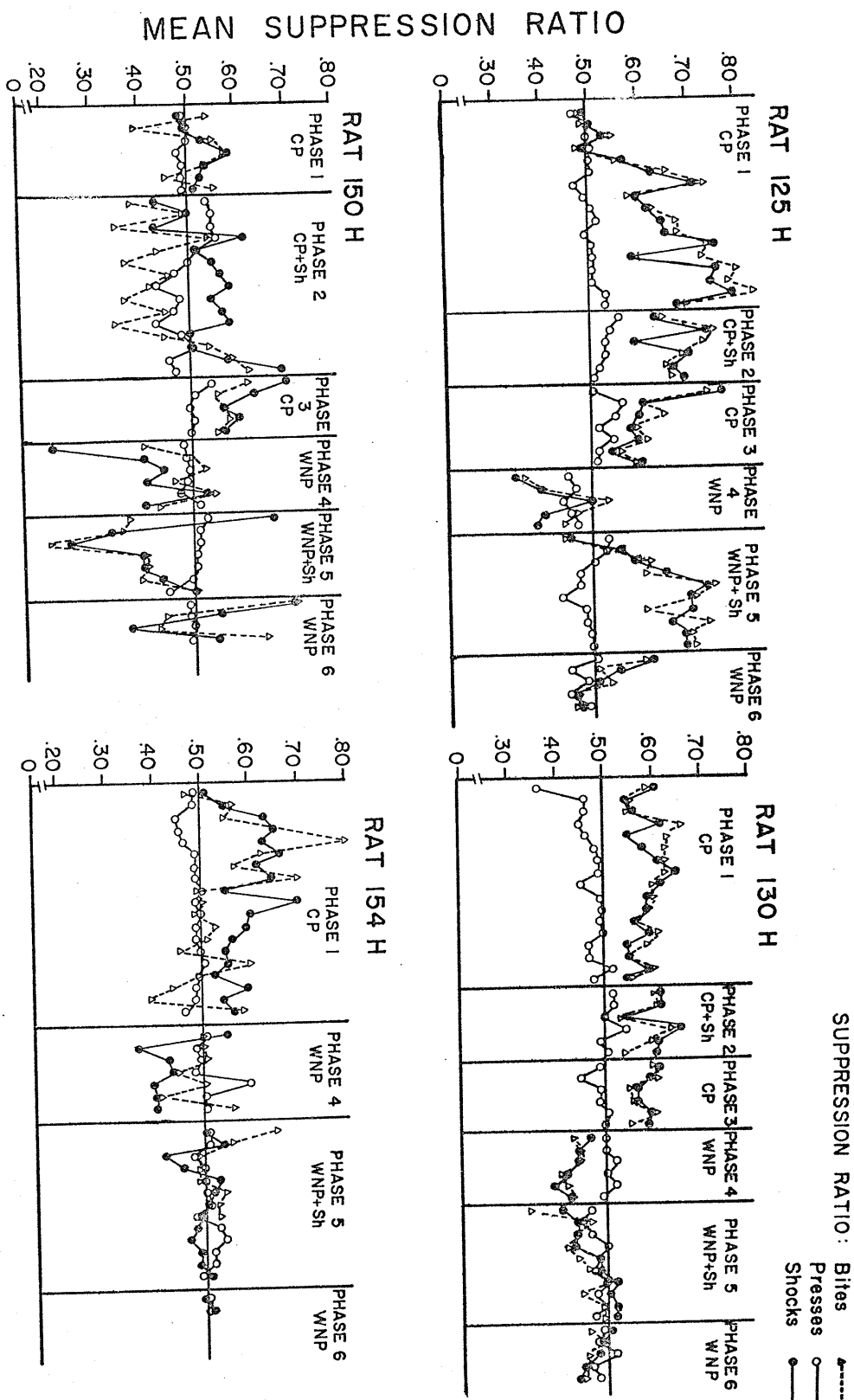
RESULTS

Suppression ratios.

Phases 1 - 3. Figure 1 shows suppression ratios for lever presses, bites, and avoidable shocks for all rats over each phase of the experiment. Each point on Figure 1 shows the mean suppression ratio over four consecutive sessions. Recall that a suppression ratio greater than 0.50 reflects a greater frequency during CPs (Phase 1 - 3) or WNPs (Phases 4 - 6) than during equal periods of session time before CPs or WNPs.

The left hand panels in Figure 1 show the suppression ratios for all rats during Phase 1, in which one-minute clicker presentations (CPs) were imposed on the avoidance schedule and were not followed by shock. It can be seen that for three subjects, 125H, 150H, and 154H, suppression ratios for all three events -- bites, presses, and avoidable shocks -- were close to 0.50 during the initial sessions, indicating little difference in responding before and during CPs. For rat 125H, suppression ratios were close to 0.50 for 16 sessions; suppression ratios for subject 150H were close to 0.50 for 8 sessions; suppression ratios for subject 154H were near 0.50 for 4 sessions; and,

Figure 1. Suppression ratios for lever presses, lever bites, and avoidable shocks for all subjects over each phase of the experiment. Each point represents the mean suppression ratio over four consecutive sessions.


MEAN SUPPRESSION RATIO
RAT 125 H
RAT 130 H
RAT 150 H
RAT 154 H
PHASE 1 CP
PHASE 2 CP+Sh
PHASE 3 CP
PHASE 4 WNP
PHASE 5 WNP+Sh
PHASE 6 WNP
SUPPRESSION RATIO: Bites
Presses
Shocks
BLOCKS OF FOUR SESSIONS

subject 130H showed differences in responding between CPs and other recorded session time immediately.

When suppression ratios for shocks are examined in Figure 1, it is apparent that all subjects showed some suppression of avoidance responding during CPs in Phase 1. That is, all subjects in most sessions received more avoidable shocks during CPs than during equal periods of session time during which the clicker was absent and white noise was present.

Suppression ratios for lever bites closely corresponded to suppression ratios for avoidable shocks, particularly in the data of subjects 125H and 130H. Lever-bite ratios for subjects 150H and 154H showed a correspondence with shock ratios for some sessions in Phase 1. An examination of the raw data indicated that subjects 150H and 154H exhibited much less lever-bite responding than subjects 125H and 130H, resulting in greater variability in bite ratios.

Results obtained from all subjects indicate that relative frequency of lever-press responding before and during CPs was not a valid measure of avoidance behavior. Although there was a definite suppression of avoidance behavior during CPs in Phase 1, indicated by shock ratios being above 0.50, and although lever biting usually showed an increase during CPs along with the increase in avoidable shocks received by all subjects, the lever-press measure did not, in most cases, reflect the avoidance

suppression that occurred during CPs. That is, the number of lever presses during CPs and during periods before CPs was nearly equal for all subjects in most sessions during Phase 1. This is shown in Figure 1 by lever-press ratios which remained close to 0.50. When these data are considered along with the shock ratios indicating a suppression of avoidance during CPs, it must be concluded that some of the lever presses recorded in the suppression ratios for lever pressing must not be avoidance responding.

Suppression ratios for subject 125H showed an increasing trend through Phase 1 indicating increased differences in responding between periods before and during CPs. This is most apparent when shock ratios and bite ratios are examined in Figure 1. Lever-press ratios showed a slight increase through Phase 1, but remained close to 0.50.

Initially, the greater number of shocks received by subject 130H during CPs was correlated with fewer lever presses during CPs. Suppression ratios for later sessions, however, did not show this inverse relationship between lever presses and avoidable shocks received by rat 130H. Figure 1 shows that, after 24 sessions, suppression ratios for lever pressing were close to 0.50. Suppression ratios for lever bites and avoidable shocks received by subject 130H were consistently above 0.50 for 68 sessions.

More variability can be seen in the data of subjects 150H and 154H, especially when bite ratios are

examined. Like the data of subjects 125H and 130H, however, avoidance suppression during CPs is apparent from shock ratios. Lever-press ratios indicate there were equal frequencies of responding before and during CPs.

For all subjects in Phase 1, therefore, more shocks were received and usually more lever biting occurred during CPs than during equal session time before CPs. From these data, it must be concluded that, while lever presses occurred with equal frequencies before and during CPs, lever-press responding was not functionally equivalent during these two periods.

When a 0.5-second unavoidable shock followed each CP in Phase 2, there was little changes in responding exhibited by subjects 125H and 130H. Figure 1 shows that, for these two subjects, suppression ratios for shocks and lever bites remained above 0.50 throughout Phase 2. As in Phase 1, more shocks were received and more biting occurred during CPs than during other recorded session time. Suppression ratios for lever pressing, however, showed small temporary increases over Phase 1 for subjects 125H and 130H and then gradually decreased to 0.50 after several sessions. For these subjects, therefore, there was initially relatively more lever pressing in Phase 2 during CPs than before CPs. It is interesting that subjects 125H and 130H received relatively more shocks during CPs even when they pressed the lever more during these periods.

Subject 150H responded somewhat differently than

subjects 125H and 130H in early sessions of Phase 2. The suppression ratios for lever bites and avoidable shocks showed an initial drop below 0.50, while the ratios for lever pressing increased to over 0.50. Thus, subject 150H lever pressed more and shocks and bites decreased during CPs relative to equal intervals of session time before CPs. After 12 sessions, however, suppression ratios for avoidable shocks increased to above 0.50, and after 20 sessions suppression ratios for lever pressing decreased to 0.50 and below. Bite ratios remained variable, usually below 0.50, although an increase is apparent in Figure 1 during the last sessions of Phase 2. An increase in avoidable shocks received by 150H also occurred during the last session of Phase 2. This is indicated by the last suppression ratio for shocks.

Subject 154H was not exposed to Phase 2.

Suppression ratios for Phase 3, during which CPs were again not followed by shock, followed a similar pattern as in previous phases. Figure 1 shows that bite ratios remained above 0.50 and lever-press ratios remained close to 0.50.

During Phase 3 and unlike Phase 1, however, subject 125H usually lever pressed slightly more during CPs than during equal session time before CPs. Figure 1 shows the press ratios for subject 125H were usually above 0.50 and were slightly higher in Phase 3 than in Phase 2, the increased lever-press responding during CPs was not correlated

with increased shock avoidance during CPs. More shocks were received and more lever biting occurred during CPs than before CPs. The suppression ratios for bites and shocks were somewhat lower in Phase 3 than in previous phases, indicating that, for subject 125H, the relative difference in measures of lever bites and shocks between periods before and during CPs was less for Phase 3 than for Phase 2.

For subject 130H, suppression ratios for bites and shocks showed no systematic change from Phase 2 or Phase 1. The suppression ratios for lever pressing decreased temporarily to below 0.50 and then returned to 0.50. Again, more shocks were received and more biting occurred during CPs than before CPs, even though the frequency of lever pressing was usually similar during these periods.

Suppression ratios for subject 150H showed that, unlike previous sessions, both shocks and lever biting occurred at a consistently higher frequency during CPs than before CPs. Lever-press ratios were initially above 0.50, showing an increase from Phase 1 and Phase 2, but then returned to 0.50 and below. Similar to subjects 125H and 130H, avoidance suppression occurred in Phase 3 during CPs, even though lever-press ratios did not reflect suppression.

Subject 154H was not exposed to Phase 3.

In summary, during Phase 1 avoidance suppression, indicated by shock ratios which were above 0.50, occurred for all subjects during CPs. Bite ratios usually

corresponded closely with shock ratios except when the frequency of biting was very low. Suppression ratios for lever-pressing remained near 0.50 thereby proving to be an invalid measure of avoidance suppression. The pairing of CPs with unavoidable shock for three subjects during Phase 2 resulted in small temporary changes in lever-press ratios for all three subjects, and a temporary change in shock ratios for one subject. After several sessions, however, suppression ratios showed no differences from Phase 1. The removal of unavoidable shock in Phase 3 (i.e., a reversal to Phase 1) resulted in no consistent changes in suppression ratios for any subject. Through Phases 1 to 3, therefore, more avoidable shocks were received and more lever biting occurred during CPs than during equal session time during which the clicker noise was absent and white noise was present. Lever pressing occurred at similar frequencies before and during CPs.

Phases 4 - 6. During these phases, the 30 one-minute CPs were changed to white noise presentations (WNPs) and the 90 minutes which, in previous phases, consisted of white noise, was changed to the clicker noise. Rat 154H was exposed to Phase 4 immediately after Phase 1. No unavoidable shocks were delivered during Phases 4 and 6. A 2.0 mA, one second unavoidable shock was delivered upon the termination of each WNP during Phase 5.

Figure 1 shows that, for all rats, the suppression ratios for shocks dropped below 0.50 when the auditory

stimuli in the experiment were reversed in Phase 4. That is, all subjects received fewer shocks during WNPs than during equal session time during which white noise was absent and the clicker noise was present.

Suppression ratios for bites also decreased. For subject 125H and 130H bite ratios closely paralleled shock ratios, and, except for one point, were below 0.50. Bite ratios for subject 150H were lower than previous phases, and also paralleled shock ratios, but varied around 0.50. Bite ratios for subject 154H remained variable around 0.50 and showed little change from Phase 1.

Lever-press ratios showed little change from previous phases for three subjects, 130H, 150H, and 154H. These ratios remained close to 0.50. Press ratios for subject 125H, however, were consistently below 0.50, showing a decrease from previous phases. Therefore, rat 125H lever pressed at a lower frequency during WNPs than during equal periods of session time during which white noise was absent and the clicker noise was present. It is interesting that, along with a lower frequency of lever pressing during WNPs, there was also a lower frequency of avoidable shocks received during WNPs relative to other measured session time. In Phase 4, as in previous phases, equal or lower frequencies of lever pressing did not result in equal or less shock avoidance in equal time periods.

When a 2 mA, one-second unavoidable shock followed each WNP in Phase 5, there was an increase in shock ratios

of all subjects. Figure 1 shows that the increase resulted in only one subject, 125H, having shock ratios which were consistently and substantially above 0.50. Bite ratios for subject 125H also increased and remained above 0.50. Press ratios for subject 125H increased from Phase 4 and were initially greater than 0.50 during Phase 5. They decreased after 8 sessions, however, and dropped to 0.50 and below, and increased again after 24 sessions. Thus, for subject 125H, more shocks were received and more biting occurred, with the same or a lower frequency of lever pressing, during WNPs than before WNPs.

Initially, subject 130H showed little change in shock ratios from Phase 4 to Phase 5. It can be seen in Figure 1 that there was an increasing trend, and during the last 16 sessions of Phase 5, shock ratios were slightly above 0.50. Bite ratios remained below 0.50 but showed a close correlation with shock ratios. Press ratios for subject 130H also showed an increasing trend, but remained slightly lower than press ratios of Phase 4. Thus, for subject 130H, there was a similar, or slightly lower frequency of presses, bites, and avoidable shocks during WNPs than before WNPs.

Subject 150H showed a facilitation of shock avoidance during most sessions in Phase 5. As can be seen in Figure 1, during most sessions subject 150H received fewer shocks and bit the lever less during WNPs than during equal session time before WNPs. The first shock ratio was high,

0.67, but the next ratio fell below 0.35 for several sessions before an increasing trend occurred. Except for the first ratio, bite ratio values were very close to shock ratio values. Suppression ratios for lever pressing showed a small increase over Phase 4, beginning at 0.54 and decreasing toward 0.50. The press ratio for the last four sessions continued this decreasing trend to 0.45. Subject 150H, therefore, usually lever pressed at a similar frequency, received fewer shocks and exhibited less lever biting during WNPs than before WNPs.

Figure 1 shows that, for subject 154H shock ratios increased in Phase 5 to close to 0.50. Lever-press and bite ratios showed no systematic changes from Phase 4, varying around 0.50. After 28 sessions in Phase 5, however, subject 154H stopped lever biting. In general, it can be stated that, during Phase 5, subject 154H showed little change in lever-press and lever-bite response frequencies and frequency of avoidable shocks when WNPs and session time before WNPs were compared.

Phase 6 consisted of a reversal to Phase 4 during which WNPs were not followed by shock. Although conditions were identical, shock ratios for all subjects were higher in Phase 6 than in Phase 4. In Figure 1 it can be seen that subject 125H showed lower shock ratios than shown in Phase 5. Shock ratios for this subject gradually fell to 0.50 and below, but they did not decrease to the values of shock ratios in Phase 4.

Initially subject 130H showed shock ratios of just above 0.50, which were similar to the shock ratios of Phase 5. These ratios, like those of rat 125H, also decreased over Phase 6 to values below 0.50.

Shock ratios for subject 150H also showed this decreasing trend from an initially high 0.70 to 0.37, and then increased again to above 0.50. This subject showed increased shock ratios over Phases 4 and 5. Shock ratios for subject 150H showed no difference from the ratios of Phase 5, and remained close to 0.50.

For all subjects except 154H (which had stopped biting during Phase 5) suppression ratios for lever biting closely corresponded with suppression ratios for shocks.

It can also be seen in Figure 1 that suppression ratios for lever pressing for all subjects were initially very close to 0.50, ranging from 0.49 to 0.51. For one subject, 125H, press ratios decreased and remained closer to 0.45.

During Phase 6, therefore, shock ratios for all subjects were higher than the shock ratios of Phase 4. Two subjects showed little difference from Phase 5 in shock ratios, one subject showed an increase and one showed a decrease from Phase 5. Bite ratios closely corresponded to shock ratios. Lever press ratios showed little change from Phase 5 and remained close to 0.50.

In summary, for all four subjects, the suppression ratios for shocks decreased to below 0.50 when the auditory

stimulus dimensions of the experiment were reversed in Phase 4. That is, fewer shocks were received during WNPs than during equal session time during which the white noise was absent and the clicker noise was present. Corresponding to the decreased shock ratios, bite ratios also decreased from previous phases. Bite ratios for two subjects were below 0.50, and for two subjects bite ratios varied around 0.50. Lever-press ratios for three subjects remained close to 0.50. For the other subject, 125H, press ratios decreased to below 0.50, indicating that there was less lever pressing as well as fewer shocks received during WNPs than before WNPs.

During Phase 5 when an unavoidable shock followed each WNP, an increase in shock ratios over Phase 4 was observed for all subjects. Bite ratios increased and again showed a close correspondence to shock ratios. Only one subject, however, responded so as to receive more shocks during WNPs than during other measured session time. No consistent changes were observed in press ratios although they varied closely above or below 0.50.

During Phase 6 the unavoidable shock was eliminated. Two subjects showed little change in shock ratios; one subject showed an increase and one subject showed a decrease from Phase 5. Bite ratios corresponded to shock ratios and lever-press ratios showed little change from Phase 5, remaining near 0.50.

Avoidable shocks received per session.

Figure 2 shows the total avoidable shocks per session received by subjects 125H, 130H, 150H, and 154H during each phase of the experiment. Each point represents the average avoidable shocks received by the subject over four consecutive sessions. The first eight sessions of Phase 1 are omitted because during these initial "acquisition" sessions all subjects received a relatively large number of shocks.

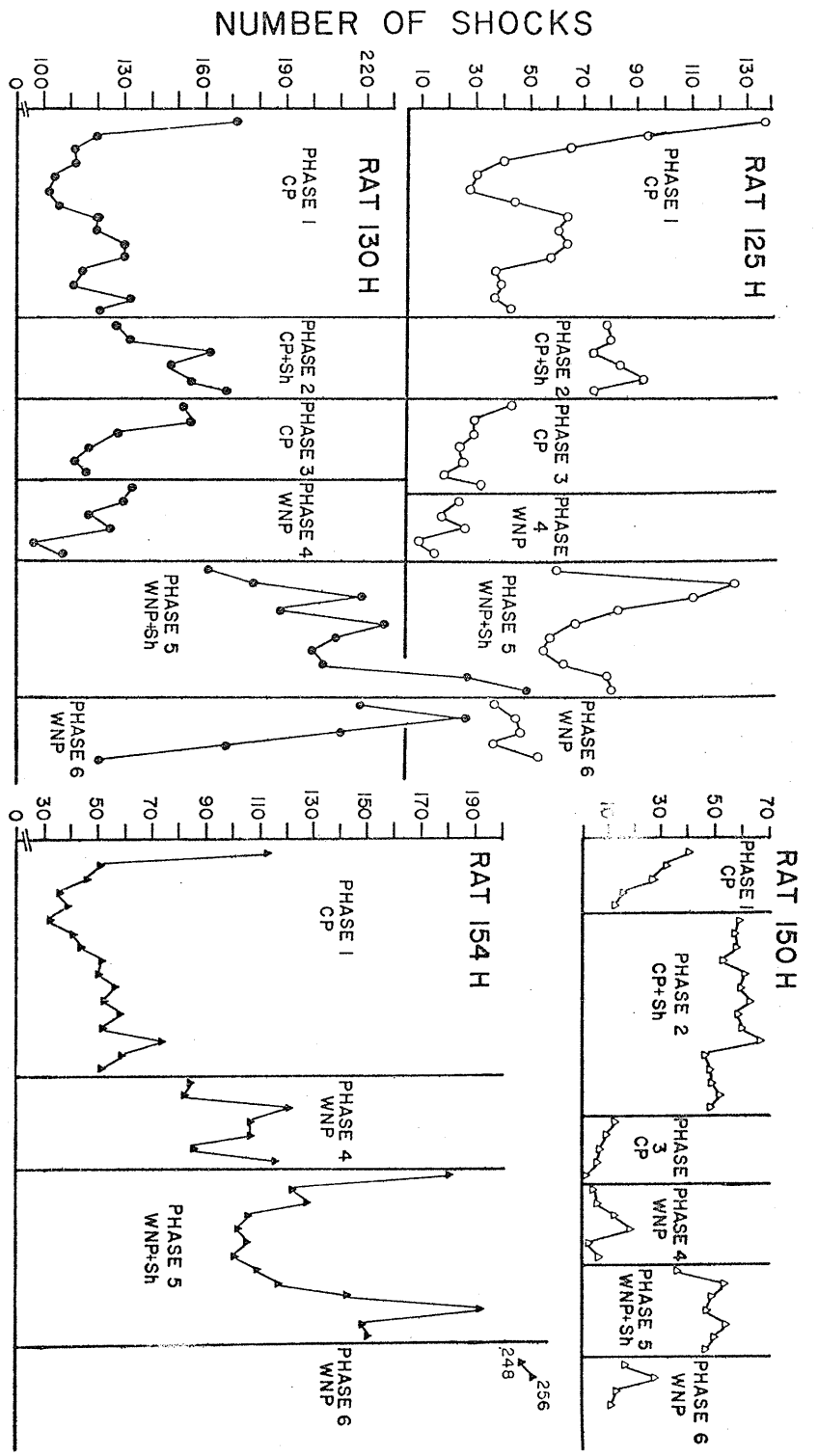
During Phase 1, following initial sessions, shocks were most consistently avoided by subject 150H. Subject 130H received the most shocks per session, usually receiving well over 100 avoidalbe shocks. Subjects 125H and 154H showed close to the same efficiency of avoidance behavior, even though, as will be shown later, subject 125H responded at a much higher rate following shock.

It can be seen in Figure 2 that, when an unavoidable shock occurred immediately after each CP in Phase 2, all subjects received more avoidable shocks per session than they received in Phase 1. Examination of the suppression ratios for shocks in Figure 1, as well as the raw data, revealed that impaired avoidance occurred throughout the session and was not confined to periods of CPs preceding unavoidable shock.

When the unavoidable shock contingency was removed in Phase 3, the total avoidable shocks per session received

Figure 2. Total avoidable shocks per session received by all subjects over each phase of the experiment. Each point represents the mean shocks over four consecutive sessions. The first eight sessions are omitted.

THE UNIVERSITY OF MANITOBA LIBRARIES


NUMBER OF SHOCKS
RAT 125 H
PHASE 1 CP
PHASE 2 CP+Sh
PHASE 3 CP
PHASE 4 WNP
PHASE 5 WNP+Sh
PHASE 6 WNP
RAT 130 H
PHASE 1 CP
PHASE 2 CP+Sh
PHASE 3 CP
PHASE 4 WNP
PHASE 5 WNP+Sh
PHASE 6 WNP
RAT 150 H
PHASE 1 CP
PHASE 2 CP+Sh
PHASE 3 CP
PHASE 4 WNP
PHASE 5 WNP+Sh
PHASE 6 WNP
RAT 154 H
PHASE 1 CP
PHASE 4 WNP
PHASE 5 WNP+Sh
PHASE 6 WNP
256
248
BLOCKS OF FOUR SESSIONS

by rats 125H, 130H, and 150H decreased. (It will be recalled that subject 154H was not exposed to Phases 2 and 3). The decrease was immediate and pronounced for subjects 125H and 150H and gradual for subject 130H.

In Phase 4, the 30 one-minute CPs were changed to WNPs, resulting in 30 WNPs and 90 minutes of clicker noise per session. It can be seen in Figure 2 that, for two subjects, 125H and 130H, the total shocks received per session in Phase 4 decreased slightly and gradually from Phase 3. Subject 150H, on the other hand, received more shocks during some sessions of Phase 4 than Phase 3, but still received fewer than 20 shocks per session. Subject 154H, having been exposed to Phase 4 directly following Phase 1, received more shocks per session in Phase 4 than Phase 1. Unlike the other subjects, and apparent in Figure 2, subject 154H showed an increasing trend in avoidable shocks received per session over the four phases to which it was exposed.

During Phase 5, a 2 mA, one-second unavoidable shock occurred after each WNP. It can be seen in Figure 2 that all subjects showed a definite and dramatic increase over Phase 4 in avoidable shocks received. This increase was sustained throughout Phase 5 for subjects 125H, 130H, and 150H but, for subject 154H decreased after four sessions. The decrease was temporary and after 28 sessions in Phase 5, shocks recieved by subject 154H showed a much higher frequency than shocks received in Phase 4. As in

Phase 2, the increase in avoidable shocks was not confined to periods (WNPs) which signalled shock, but occurred throughout the session.

When the unavoidable shock contingency was removed in Phase 6, the total number of shocks received per session decreased for three of the four subjects. The decrease was not to the level of avoidable shocks received during Phase 4 although experimental conditions were the same in Phases 4 and 6. Figure 2 suggests that, for subjects 130H and 150H, the number of avoidable shocks per session may have reached the Phase 4 level if more sessions had been given. One subject, 154H, received a greater number of avoidable shocks during Phase 6 sessions than it had received in any previous sessions. This rat's avoidance behavior may have been disrupted due to illness since it died after its eighth session in Phase 6.

In summary, all subjects avoided shocks, with subject 150H avoiding most shocks and subject 130H avoiding the least number of shocks. When an unavoidable shock followed each CP (Phase 2) or each WNP (Phase 5), the total number of shocks received per session by all subjects increased. When the unavoidable shock contingencies were removed in Phases 3 and 6, avoidable shocks decreased for all subjects except 154H. Subject 154H was not exposed to Phases 2 and 3, and showed an increasing trend in avoidable shocks received over the four phases to which it was exposed.

Post-shock response distributions.

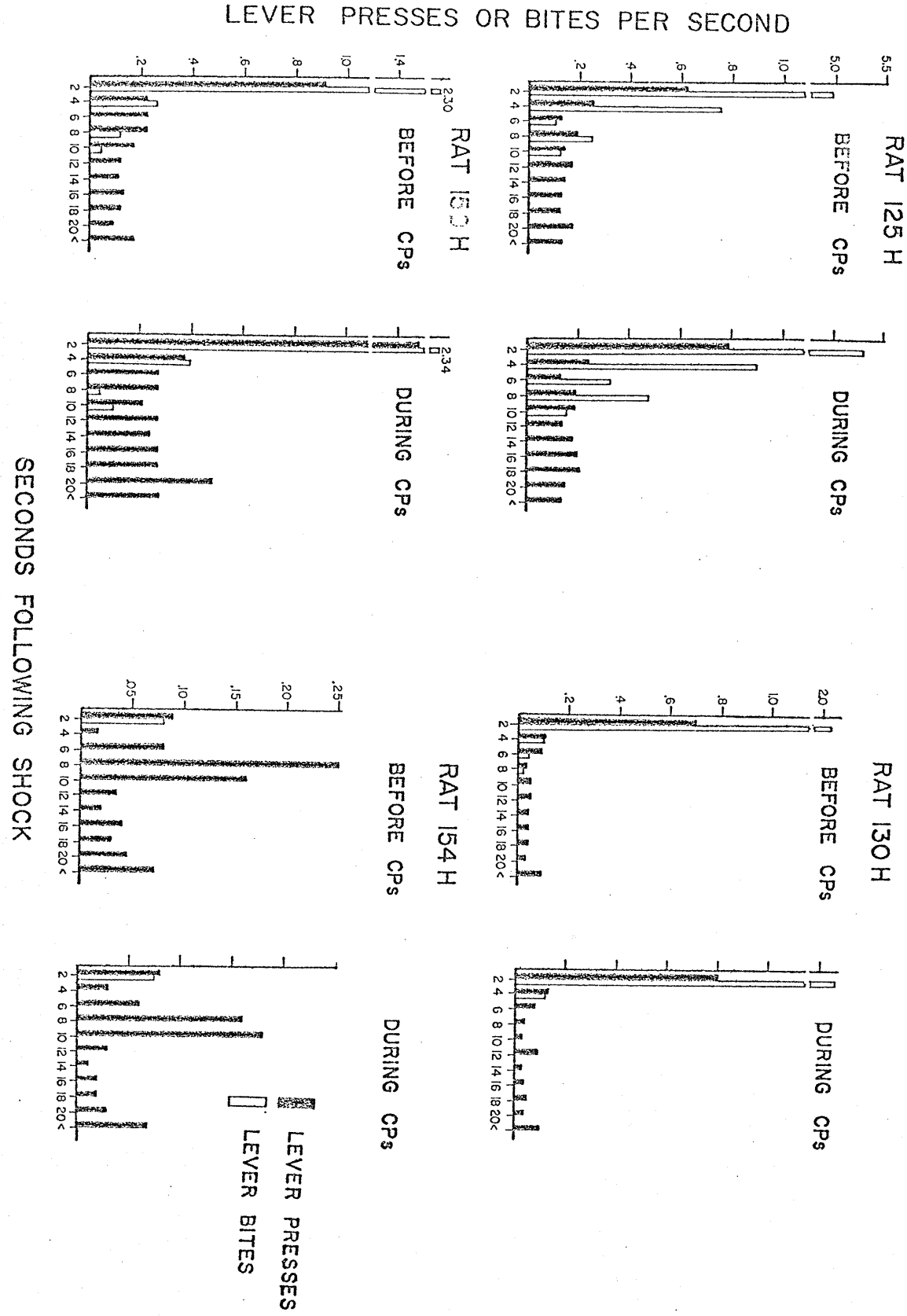
Figure 3 shows the rates of lever pressing and lever biting per second in two-second intervals following shock. Rates are shown for equal session time before and during CPs for subjects 125H, 130H, 150H, and 154H. The last interval is the period extending beyond 20 seconds following shock. Rate was determined by dividing the total number of presses and bites in each interval during the last 8 sessions of Phase 1, by the total amount of time spent by the subject in that interval during those 8 sessions.

For subjects 125H, 130H, and 150H, rates of lever pressing and biting both before CPs and during CPs were much higher during the first two seconds following shock than during later intervals. For these three subjects, lever bites occurred at a higher rate than lever presses in the first interval after shock.

When rates during later intervals are compared, it can be seen from Figure 3 that subjects 125H and 150H lever-pressed at higher rates than subject 130H. It will be recalled that subject 130H received many more avoidable shocks per session than the other subjects (see Figure 2). Subject 150H received very few shocks per session and exhibited the highest rates of responding in later intervals following shock (see Figures 2 and 3).

Subject 154H did not show the same post-shock pattern and rates of lever pressing and lever biting as did

Figure 3. Post-shock lever-press and post-shock lever-bite rate distributions before and during CPs for all rats during the last eight sessions of Phase 1.

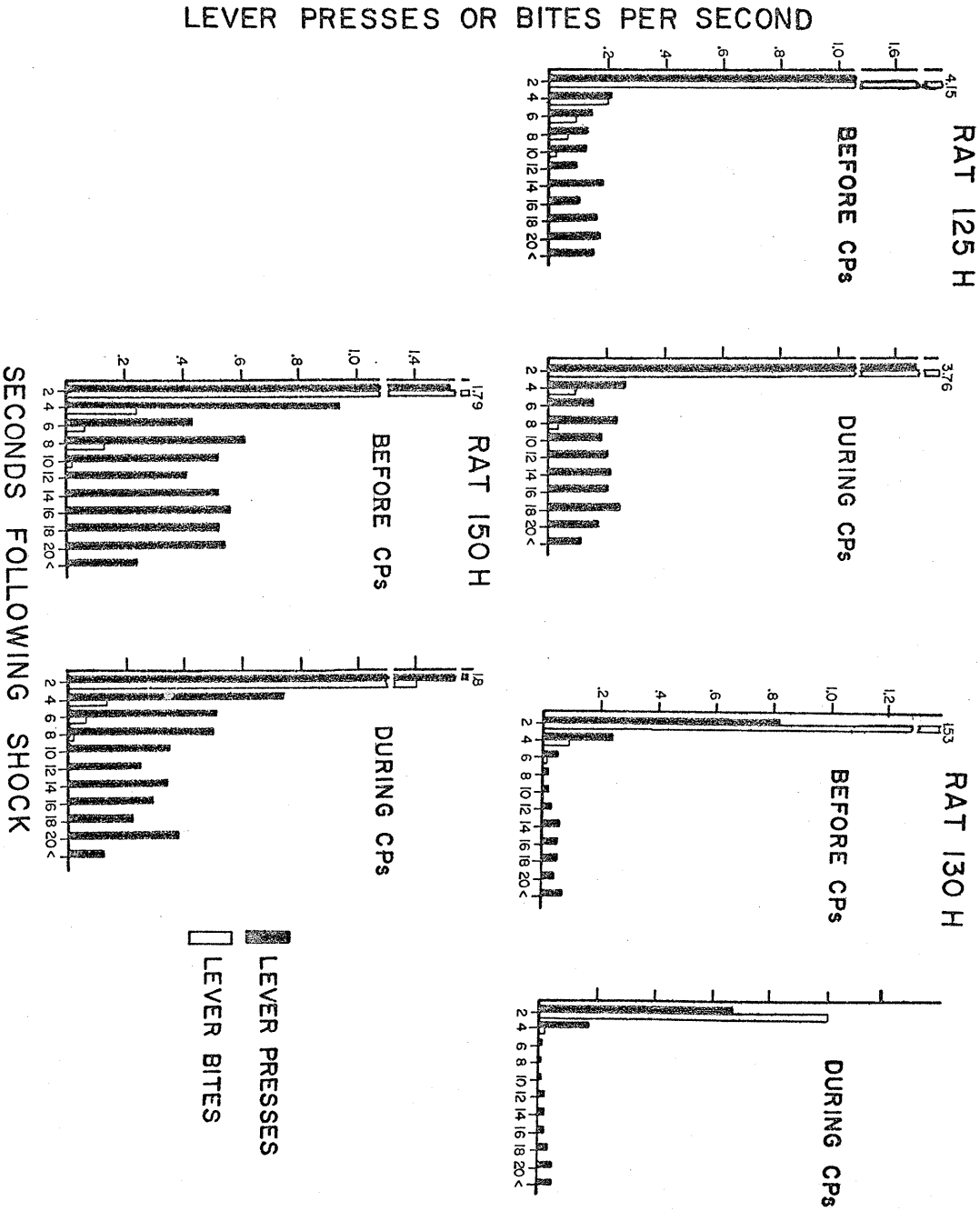

PHASE I: CP
RAT 125 H
RAT 153 H
RAT 130 H
RAT 154 H
BEFORE CPs
DURING CPs
LEVER PRESSES OR BITES PER SECOND
SECONDS FOLLOWING SHOCK
LEVER PRESSES
LEVER BITES

the other subjects. Post-shock lever biting occurred only in the first two seconds following shock and showed much lower rates than rates exhibited by other subjects. Lever-press responding occurred at the highest rates in the intervals occurring 8 and 10 seconds after shock, but even these rates were very low. (Note the different scale in Figure 3 for subject 154H).

When rates before and during CPs are compared, it can be seen that three subjects, 125H, 130H, and 150H, lever-pressed and bit the lever at a higher rate in the first interval after shock during CPs than before CPs. This might be related to the greater number of shocks received by these subjects during CPs (see Figure 1). Rates during later intervals were more variable, with these three subjects exhibiting a higher rate in some intervals during CPs than before CPs. Subject 154H responded at a higher rate in most intervals before CPs than during CPs.

Figure 4 shows post-shock lever-press and lever-bite rate distributions for subjects 125H, 130H, and 150H during the last eight sessions of Phase 2, in which an unavoidable shock followed each CP. For these three subjects, lever-press and lever-bite response bursting occurred in the first two-second interval following shock as it did in Phase 1. The rates of biting in the first intervals, however, were less in Phase 2 than in Phase 1 both before and during CPs for all three subjects. Rates of lever pressing, on the other hand, were usually higher in Phase 2 than in

Figure 4. Post-shock lever-press and post-shock lever-bite rate distributions before and during CPs for rats 125H, 130H, and 150H during the last eight sessions of Phase 2.

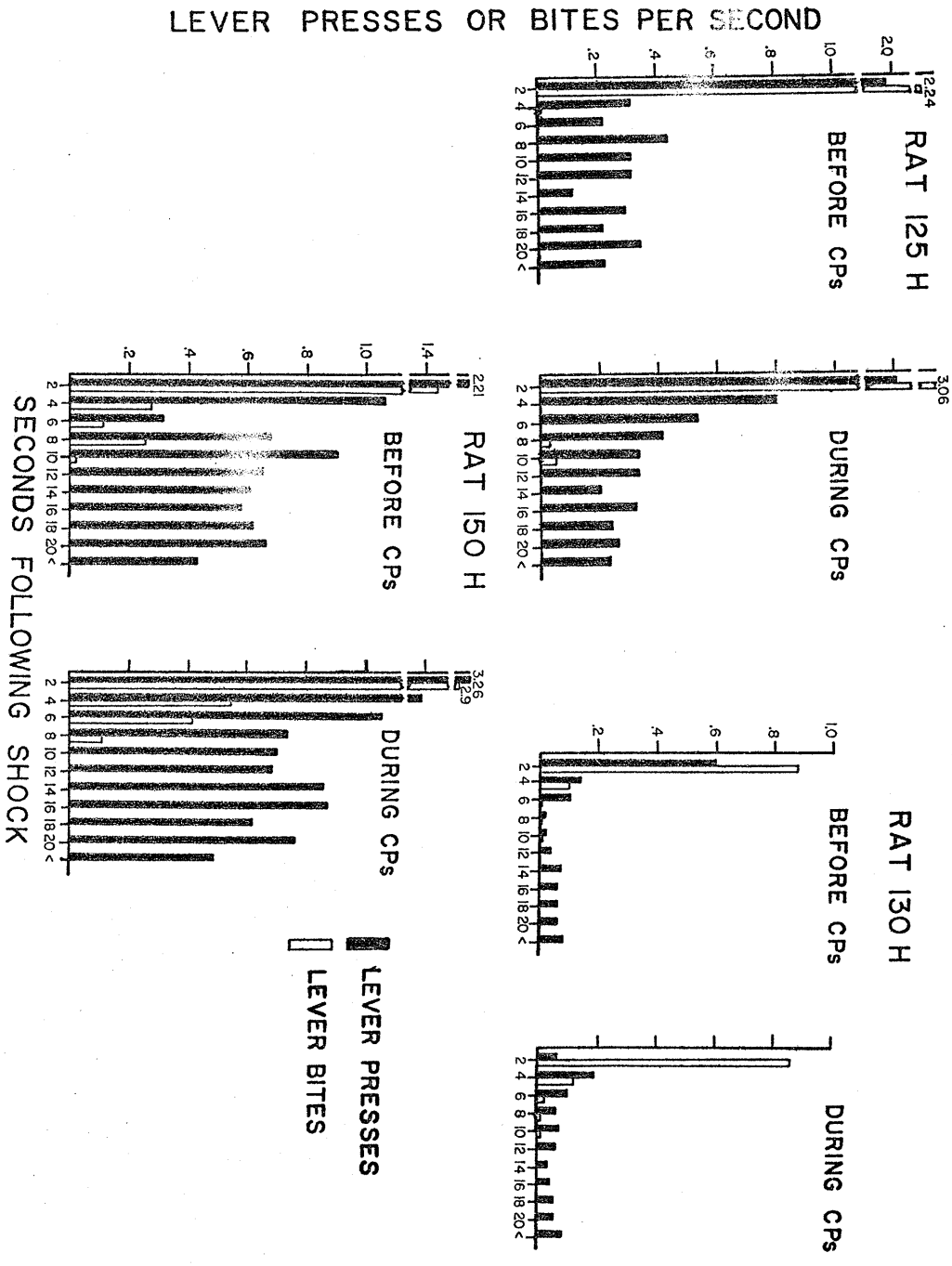

PHASE 2: CP+Sh
RAT 125 H
RAT 130 H
RAT 150 H
BEFORE CPs
DURING CPs
LEVER PRESSES OR BITES PER SECOND
SECONDS FOLLOWING SHOCK
LEVER PRESSES
LEVER BITES

Phase 1 during the first interval following shock. Rates during later intervals following shock showed little difference from Phase 1 to Phase 2 for subject 125H, decreased slightly for subject 130H, and increased substantially for subject 150H.

When rates before and during CPs are compared in Figure 4, one subject, 125H, responded at higher rates during CPs in later intervals following shock and the other two subjects responded at a slightly lower rate during CPs than before CPs. Therefore, although all subjects received consistently more avoidable shocks in Phase 2 (see Figure 2) and although all subjects received consistently more shocks during CPs than before CPs (Figure 1), post-shock response rate distributions in Figure 4 do no reflect this consistency.

During Phase 3, however, when the unavoidable shock contingency was removed and avoidable shocks per session decreased, two out of three subjects exhibited decreased response bursting in the first post-shock interval, and all three subjects increased their rates of responding in later intervals following shock. Figure 5, which shows post-shock lever-press and lever-bite rate distributions following shock for Phase 3, shows increased rates of responding from Phase 2 (Figure 4) in most intervals following shock (excluding the first interval). Subject 150H responded at exceptionally high rates following shock. It can be seen in Figure 2 that subject 150H received very few shocks per

Figure 5. Post-shock lever-press and post-shock lever-bite rate distributions before and during CPs for rats 125H, 130H, and 150H during the last eight sessions of Phase 3.


LEVER PRESSES OR BITES PER SECOND
PHASE 3: CP
RAT 125 H
BEFORE CPs
DURING CPs
RAT 130 H
BEFORE CPs
DURING CPs
RAT 150 H
BEFORE CPs
DURING CPs
LEVER PRESSES
LEVER BITES
SECONDS FOLLOWING SHOCK

session.

Figure 5 shows no consistent differences in response rates before and during CPs.

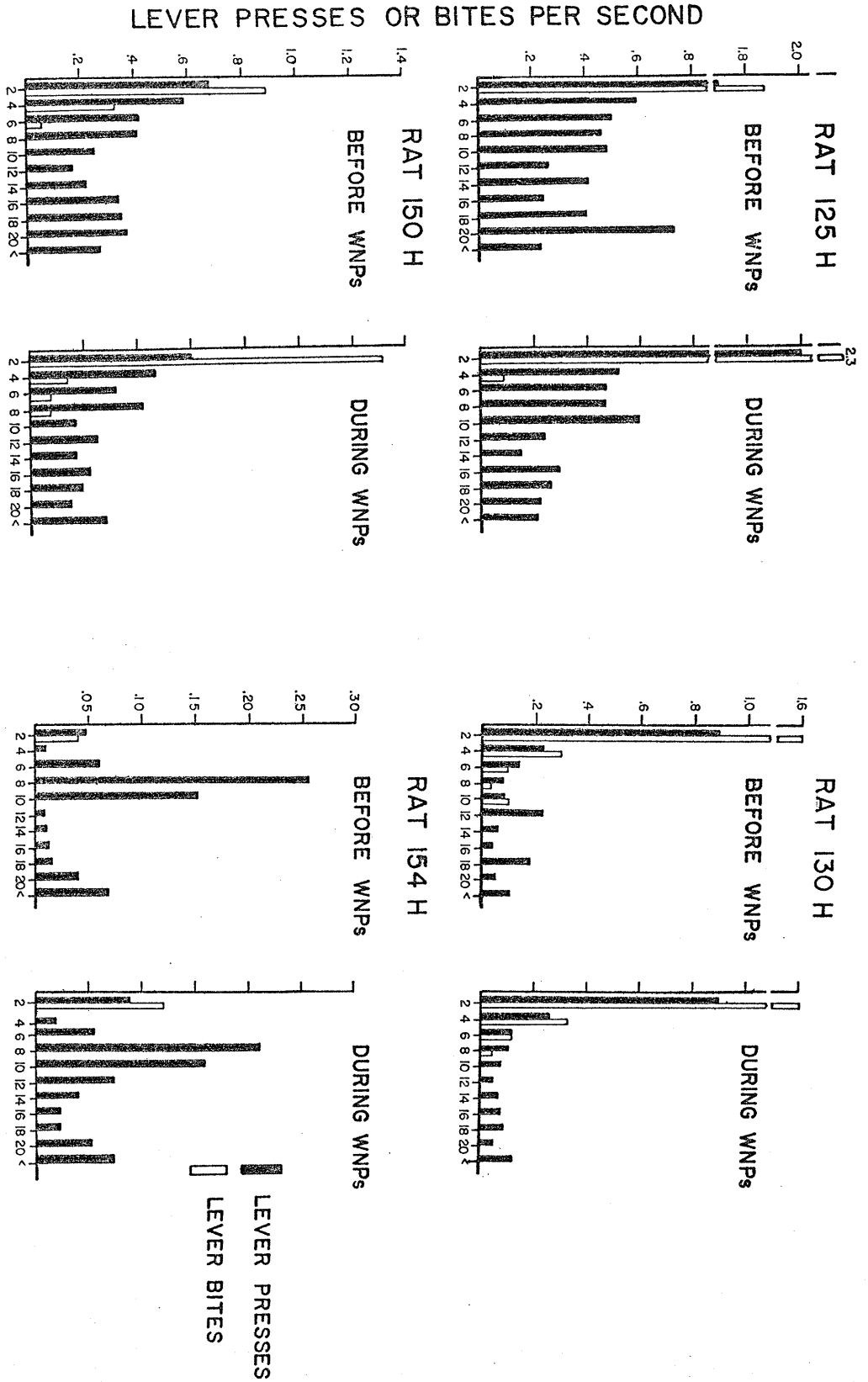
Figure 6 shows post-shock lever-press and lever-bite rate distributions for all subjects during the last eight sessions of Phase 4. When Figures 5 and 6 are compared it can be seen that subject 125H showed a decrease in rates of pressing and biting during the first interval following shock and an increase in lever-press rates in most other intervals both before and during WNPs. Subject 130H also showed an increased rate in most intervals following shock both before and during WNPs. Note that these two subjects, 125H and 130H showed improved avoidance (see Figure 2) along with increased rates of lever pressing during later intervals.

Subject 150H showed a decrease from Phase 3 in lever-press and bite rates in all intervals following shock.

Subject 154H showed little change from Phase 1 in rate or pattern of response distribution. Rates were much lower than the rates of other subjects and the highest rates of lever pressing again occurred in the 8 and 10 second intervals after shock. Figure 6 shows that there were few bites, but when biting occurred, it was in the first interval following shock.

There were no consistent differences in responding between periods before and during WNPs in Phase 4.

Figure 6. Post-shock lever-press and post-shock lever-bite rate distributionsbefore and during WNPs for all rats during the last 8 sessions of Phase 4.


PHASE 4: WNP
RAT 125 H
RAT 150 H
RAT 130 H
RAT 154 H
BEFORE WNPs
DURING WNPs
LEVER PRESSES OR BITES PER SECOND
SECONDS FOLLOWING SHOCK
LEVER PRESSES
LEVER BITES

During Phase 5 an unavoidable shock followed each WNP. Figure 7 shows the post-shock lever-press and post-shock lever-bite rate distributions for all rats during the last eight sessions of Phase 5. It can be seen that all subjects increased lever-press and/or bite bursting in the first interval following shock. Subject 154H exhibited lever-press and lever-bite bursting for the first time in Phase 5, although at a much lower rate than the other subjects.

When Figures 6 and 7 are compared, it is apparent that subjects 125H and 130H exhibited an increase in rate of post-shock biting from Phase 4 to Phase 5 both before and during WNPs. Subjects 150H and 154H showed an increase over Phase 4 in both press and bite response rates in the first interval following shock before and during WNPs. This increased response bursting may have been related to the increase in avoidable shocksreceived by all subjects during Phase 5 (see Figure 2). Moreover, subjects 125H and 130H showed definite decreases from Phase 4 in response rates during later intervals following shock. Subjects 150H and 154H showed decreased response rates in some later intervals.

It can be seen in Figure 7 that subjects 125H, 150H, and 130H lever-press responded at lower rates in most intervals during WNPs than before WNPs. Subject 154H showed no consistent differences in response rates during later intervals following shock.

Figure 7. Post-shock lever-press and post-shock lever-bite rate distributions before and during WNPs for all rats during the last eight sessions of Phase 5.

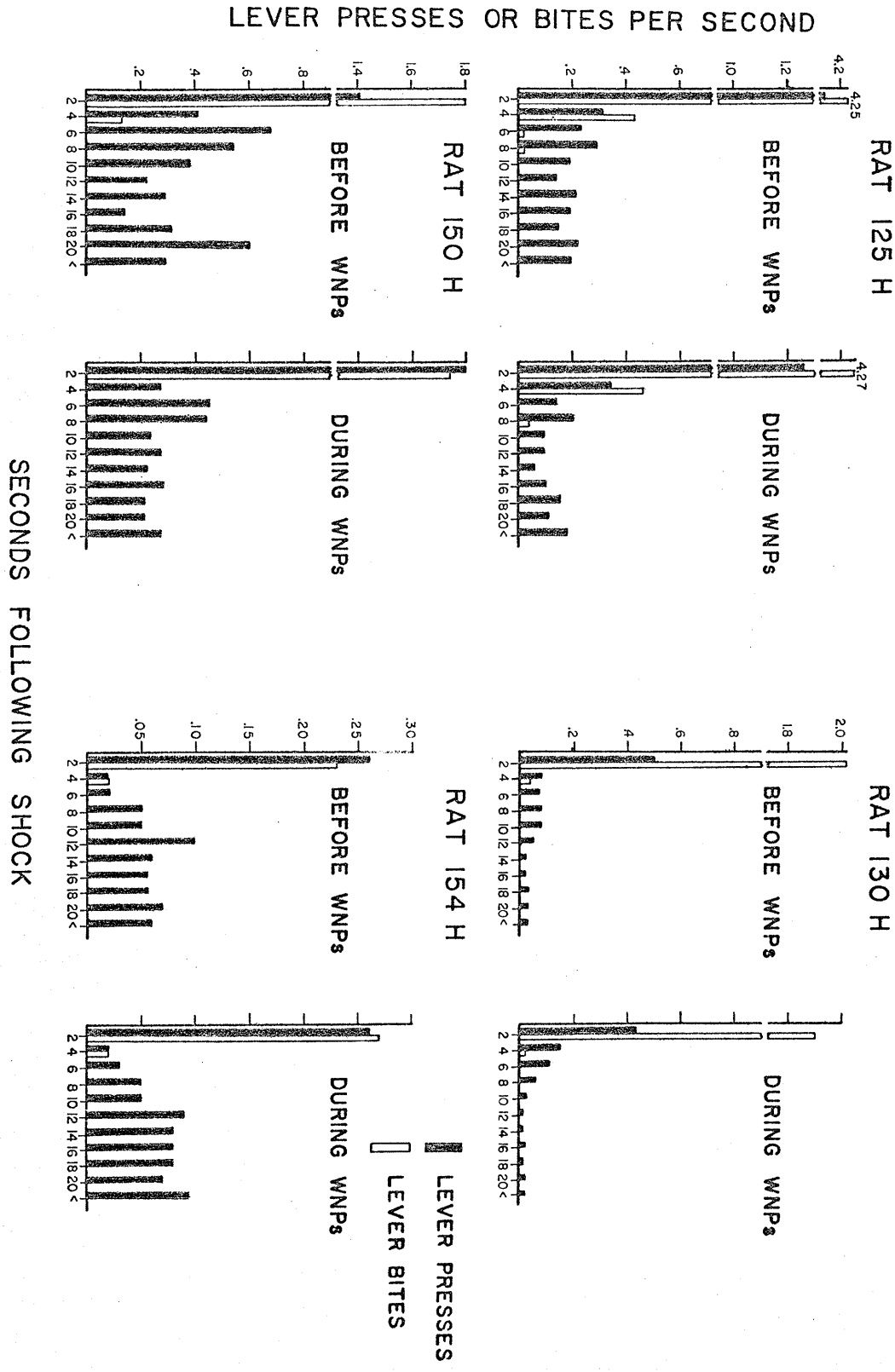

PHASE 5: WNP+Sh
LEVER PRESSES OR BITES PER SECOND
RAT 125 H
RAT 150 H
RAT 130 H
RAT 154 H
BEFORE WNPs
DURING WNPs
LEVER PRESSES
LEVER BITES
SECONDS FOLLOWING SHOCK

Figure 8 shows the post-shock lever-press and bite rate distribution for all subjects during the last eight sessions of Phase 6, in which the unavoidable shock following each WNP was removed. Corresponding to the decrease in avoidable shocks shown in Figure 2, it can be seen in Figure 8 that the rates of lever pressing and lever biting in the first interval following shock decreased from Phase 5 for all subjects both before and during WNPs.

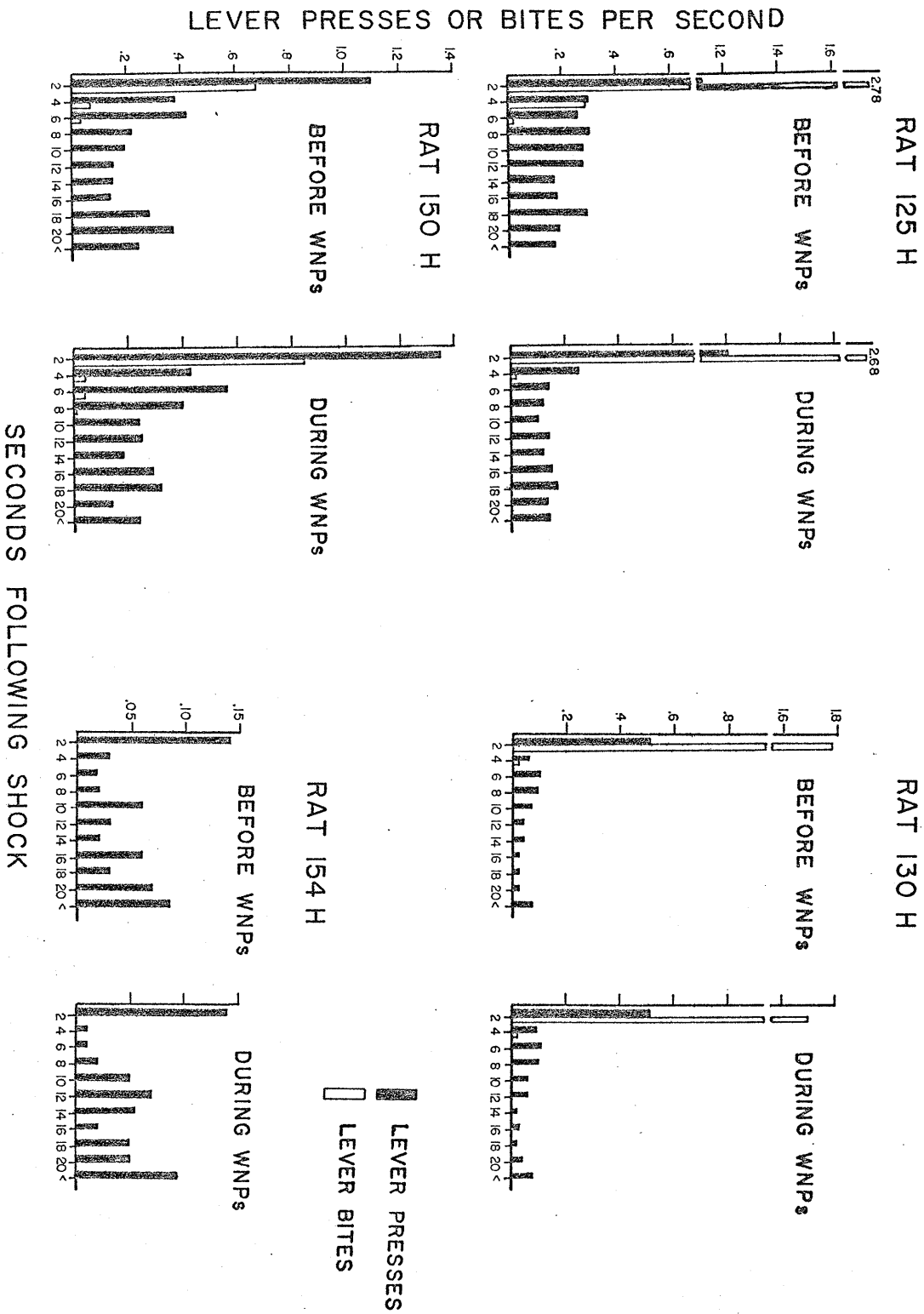
Figure 8 also indicates that response rates during later intervals following shock increased slightly from Phase 5 for subjects 125H and 130H and decreased slightly for subject 150H. Subject 154H showed decreased response rates in most intervals following shock. It can be seen in Figure 2 that this subject received a great many avoidable shocks during Phase 6.

There were no consistent differences in response rates before and during WNPs in Phase 6.

In summary, the response rate distribution data shows that all subjects in most phases exhibited post-shock lever press and lever-bite response bursting. Subject 154H responded at much lower rates following shock than the other three subjects and did not show post-shock bursting during Phases 1 and 4. During these phases, subject 154H responded at the highest rates 8 and 10 seconds following shock.

During Phase 1, the three subjects which showed response bursting showed more response bursting during CPs

Figure 8. Post-shock lever-press and post-shock lever-bite rate distributionsbefore and during WNPs for all rats during the last eight sessions of Phase 6.


PHASE 6: WNP
LEVER PRESSES OR BITES PER SECOND
SECONDS FOLLOWING SHOCK
RAT 125 H
RAT 150 H
RAT 130 H
RAT 154 H
BEFORE WNPs
DURING WNPs
LEVER PRESSES
LEVER BITES

than before CPs. Later intervals following shock were not consistent although, in some intervals, response rates were higher during CPs than before CPs. When the unavoidable shock contingency was introduced in Phase 2, there was in all cases except one, an increase in lever-press response bursting in the first interval following shock, although lever-bite responding decreased. Two out of three subjects showed lower rates of responding in later post-shock intervals during CPs than before CPs. There were no other consistencies across subjects.

During Phase 3, when the unavoidable shock contingency was removed, subjects 125H and 130H showed decreased lever-press and bite response bursting in the first interval following shock. Lever-press rates during later intervals after shock increased for these two subjects. Subject 150H showed increased rates in all intervals following shock. It was noted that shock avoidance increased for all three subjects in Phase 3. There were no consistent differences in rates between periods before and during CPs.

During Phase 4 one subject, 125H, showed a decrease in post-shock lever-pressing and biting from Phase 3, and both subjects 125H and 130H showed increased rates in later intervals following shock. These subjects also showed increased shock avoidance from Phase 3. One subject, 150H, showed rate decreases in all intervals following shock, and the fourth subject, 154H, showed little change in response rates from Phase 1. Subjects responded at similar rates

before and during WNPs.

When unavoidable shocks were introduced following WNPs in Phase 5, all subjects exhibited increases in post-shock biting both before and during WNPs and two subjects also showed increased rates of post-shock lever-pressing before and during WNPs. Two subjects showed decreased response rates during all later intervals following shock, and the other two subjects showed decreased rates in some intervals. Subject 154H exhibited post-shock bursting for the first time in Phase 5, and showed decreased responding in the 8 and 10 second intervals following shock. Three subjects responded at lower rates in most intervals during WNPs than before WNPs. The fourth subject, 154H, showed no differencesin response rates before and during WNPs.

When the unavoidable shock contingency was eliminated in Phase 6, post-shock lever pressing and lever biting decreased both before and during WNPs for all subjects. There were no other consistencies among subjects in rate distributions between Phase 5 and 6 and between periods before and during WNPs.

Summary of main findings.

The main findings of each phase may be summarized as follows:

Phase 1 (CPs not followed by shock)

1. All subjects showed suppression of avoidance responding (i.e., received more shocks) during CPs.

Relative frequency of lever-press responding during CPs did not reflect this suppression.

2. Suppression ratios for lever bites usually paralleled suppression ratios for avoidable shocks.

3. Post-shock lever-press and lever-bite bursting was observed for three out of four rats. These three subjects responded at a higher rate in the first interval following shock during CPs than before CPs. Response rates in later intervals following shock were positively correlated with efficiency of avoidance behavior. The fourth subject responded at a lower rate than did the other subjects. This subject's highest rate of lever pressing occurred 8 and 10 seconds following shock.

Phase 2 (CPs followed by unavoidable shock)

1. Two of three subjects showed little difference from Phase 1 in suppression ratios for avoidable shocks and lever bites, and a temporary increase over Phase 1 in lever-press ratios. There were more avoidable shocks received by these subjects during CPs even when they exhibited more lever pressing during CPs. The third subject initially lever pressed more and received fewer shocks during CPs than before CPs. After 20 sessions, however, this subject lever pressed less and received more shocks during CPs than before CPs.

2. Although post-shock biting decreased from Phase 1 for the three subjects exposed to this phase, rates of pressing and biting in the first interval following shock

remained much higher than rates in later intervals. Rates of lever pressing in later intervals were lower during CPs than before CPs for two subjects, and higher during CPs than before CPs for the other subject.

3. All subjects received more avoidable shocks per session during Phase 2 than during Phase 1.

Phase 3 (CPs not followed by shock)

1. For the three subjects exposed to this phase, more shocks were again received, and more biting occurred during CPs than during other session time. Suppression ratios for lever pressing remained close to 0.50, indicating frequency of lever pressing was similar before and during CPs.

2. There were no consistent changes in shock and bite ratios from Phase 2 to Phase 3. For one subject these ratios increased, for one subject they decreased, and for one subject there was no change in shock and bite ratios from Phase 2 to Phase 3.

3. Post-shock lever-press rates and post-shock lever-bite rates were again highest in the first interval following shock but showed a decrease from Phase 2 in later intervals following shock. There were no consistent differences in rates between periods before and during CPs.

4. The total number of avoidable shocks received per session by all three subjects exposed to this phase decreased from Phase 2 to Phase 3.

Phase 4 (WNPs not followed by shock)

1. For all four subjects, the suppression ratios for shocks decreased to below 0.50. That is, fewer shocks were received during WNPs than during equal session time during which the white noise was absent and the clicker noise was present.

2. Corresponding to the decreased shock ratios, bite ratios also decreased from previous phases. Bite ratios for two subjects were below 0.50, and, for two subjects, varied around 0.50.

3. Lever-press ratios for three subjects remained close to 0.50. For the other subject, 125H, lever-press ratios decreased to below 0.50, indicating that there was less lever pressing as well as fewer shocks received during WNPs than before WNPs.

4. Similar to Phase 1, three of the four subjects exhibited lever-press and lever-bite response bursting following shock. The fourth subject, 154H, responded at its highest rate 8 and 10 seconds following shock. There were no consistent differences in response distributions before and during WNPs.

5. Two subjects showed small decreases from Phase 3 to Phase 4 in avoidable shocks received; one subject, 154H, received an increase in avoidable shocks from Phase 1 to Phase 4; the other subject showed no change.

Phase 5 (WNPs followed by unavoidable shock)

1. An increase over Phase 4 in shock ratios was observed for all subjects. Bite ratios increased and

showed a close correspondence to shock ratios. Only one subject, however, responded as to receive more shocks during WNPs than during other recorded session time.

2. All subjects exhibited more response bursting in the first interval following shock, both before and during WNPs, than exhibited during Phase 4. Subject 154H exhibited post-shock bursting for the first time in Phase 5. Two subjects showed decreased response rates in all later intervals following shock and two subjects showed decreased response rates in some later intervals. Again there were no consistent differences in response distributions before and during WNPs.

3. All subjects received more avoidable shocks per session during Phase 5 than during Phase 4.

Phase 6 (WNPs not followed by shock)

1. Two subjects showed little difference from Phase 5 in shock ratios; one subject showed an increase and another showed a decrease. Bite ratios corresponded to shock ratios. Lever-press ratios showed little change and remained near 0.50.

2. Post-shock lever pressing and biting decreased from Phase 5 both before and during WNPs for all subjects.

3. The total number of avoidable shocks received per session decreased from Phase 5 to Phase 6 for three subjects. The decrease did not reach the Phase 4 level.

DISCUSSION

Overview.

The results of the present experiment can be categorized into four related areas for the purpose of discussion. The first area concerns the measurement of suppression. Previous studies (e.g., Sidman et al., 1957) have used relative lever-press frequencies before and during a pre-shock signal as a measure of suppression of free-operant avoidance behavior and typically reported an increase in response rate, or facilitation of avoidance behavior, during the pre-shock signal. If lever pressing alone were used as the suppression measure in the present study, all four subjects would have shown no suppression of avoidance behavior during the clicker alone, and three out of four subjects would have shown temporary response facilitation when the clicker was followed by shock. It is apparent that the lever-press frequency alone is not a sufficient measure and may lead to erroneous conclusions. In order to clarify the results obtained in the present study, as well as qualify findings obtained in previous studies, the dynamics of the suppression measure will be given first consideration in the discussion to follow.

The second, and most surprising, result of the present experiment concerns the finding that avoidance was suppressed in all rats during presentations of the clicker stimulus, regardless of whether or not the clicker was followed by unavoidable shock and regardless of whether or not the clicker was the predominant stimulus during experimental sessions. These results suggest that avoidance suppression obtained in some of the earlier studies (viz., those that did not obtain a measure of the suppressive effect of the signal alone) was not necessarily due to signal-shock pairings, and that previous theoretical formulations of conditioned suppression may be misleading.

The third area which will be discussed relates to the results of signal-shock pairing. Although relative measures of suppression in Phase 2 revealed little or no effects of following the signal with unavoidable shock, the total avoidable shocks received per session increased for all subjects when the unavoidable shock contingency was introduced. In Phase 5, an unavoidable shock of longer duration than the avoidable shocks resulted in changes in suppression ratios.

Finally, lever-press and lever-bite response rate distributions will be discussed in an effort to relate moment-to-moment changes in responding to the more general results previewed above.

Measures of suppression.

Suppression ratios for shocks indicated that more avoidable shocks were received during the clicker than during other session time when the clicker was absent and white noise of the same intensity was present. There was also more lever biting during the clicker, apparently due to the increased number of shocks in the presence of the clicker. The frequency of lever-press responses during the clicker was, however, much the same as the frequency during other recorded session time. Given that avoidance was suppressed during the clicker, as suggested by suppression ratios for shocks, why do shock ratios and not lever-press ratios reflect this suppression?

It was suggested in the introduction of this thesis that elicited behavior, in the form of post-shock lever pressing and lever biting may have, in past research, confounded measures of operant avoidance responses (McLean, 1975; Pear et al., 1972; Pear and Hemingway, 1973; Powell, 1972). Bursts of responses, if separated by more than 20 seconds (i.e., the R-S interval), contribute little to the avoidance of shock. The rate distribution data of the present experiment indicated there was both lever-press and lever-bite bursting after shock for all subjects in all phases, except Phases 1 and 4 for subject 154H. (Subject 154H did, however, show response bursting in Phases 5 and 6). The suppression ratio data indicated more shocks were

received during CPs. With more shocks during the clicker, it follows that there were more post-shock lever-press response bursts. Therefore, the suppression ratios for avoidance responding were increased during the clicker.

It is also apparent that, with more avoidable shocks occurring during CPs, there must have been less lever pressing which functioned to avoid shocks during those periods, which should result in lever-press ratios below 0.50. Roberts and Hurwitz (1970) suggest that one should eliminate response bursts from the computation of suppression ratios for lever pressing. They suggest that if this were done, response rate and shock rate during signalled periods should become inversely related. Because suppression ratios for lever pressing in the present experiment were close to 0.50 with the inclusion of response bursts, it can be concluded that removing response bursts from the computation of lever-press ratios would probably result in a value below 0.50.

The contamination of lever-press responding as a measure of avoidance suppression is further illustrated when bite ratios are considered along with the data for lever pressing. When the data for subjects 125H and 130H are examined, it can be seen that bite ratios correspond very closely to shock ratios. Lever bites, as will be discussed later, appeared to be elicited by shock. Because there were more shocks during CPs than during other recorded session time, suppression ratios for lever bites are

above 0.50. It can be seen from the rate distribution data that lever presses also appeared to be elicited by shock. Therefore, like bite ratios, suppression ratios for lever presses must have also been increased by the disproportionate number of avoidable shocks received during the clicker. This increase in the value of lever press ratios resulted in a value near 0.50, thereby confounding the lever-press measure of suppression.

The bite ratios of subjects 150H and 154H do not correspond closely to their shock ratios. The differences in the data of these subjects as compared to the data of subjects 125H and 130H are related to the nature of relative measures. Subject 150H received very few shocks per session and, consequently, seldom bit the lever. Although subject 154H received a substantial number of shocks, the frequency of lever biting for this subject was also very low. Hence, a small change in the number of bites in one component (e.g., during CPs) of a session resulted in a large change in the ratio and increased the variability in the data of these two subjects.

Suppression ratios for Phases 4 to 6 show marked differences from Phases 1 to 3. During Phase 4 after the auditory stimuli were reversed, the suppression ratios for shocks decreased to below 0.50 for all subjects. There were fewer shocks received during the one-minute periods of white noise than during other session time during which the clicker noise was operative. For three of the four

subjects it may be argued that suppression during the clicker might be expected due to its previous association with unavoidable shock. However, these three subjects had exhibited avoidance suppression to the clicker in Phase 1, before its pairing with unavoidable shock. Moreover, for subject 154H the clicker had never been followed by unavoidable shock and the same reversal of suppression was observed. The suppressive effect of the clicker, regardless of its temporal position or duration in the session, will be discussed more fully in the next section.

For those rats for which shock and bite ratios showed close correspondence during Phases 1 to 3 -- rats 125H and 130H -- shock and bite ratios also showed close correspondence during Phases 4 to 6. Subject 150H began to lever-bite at a higher frequency during Phase 4, resulting in bite ratios for subject 150H becoming more closely correlated with shock ratios. Subject 154H had variable bite ratios due to a very low frequency of biting. This subject stopped biting midway through Phase 4.

Suppression ratios for lever pressing during Phases 4 to 6 usually remained close to 0.50. Similar to Phases 1 to 3, any suppression of avoidance lever-press responding is not reflected in lever-press ratios since the measure was, apparently, inflated by elicited lever-press bursts following shocks. In fact, the reduced number of shocks received during WNPs resulted in less lever-press response bursting during WNPs which is reflected, in some sessions,

by suppression ratios which are below 0.50 (for example, see data for subject 125H in Figure 1).

It is apparent from the present data that suppression measures can be, and probably have been, inadequate reflections of performance, especially in the free-operant avoidance situation. Hoffman (1969) has suggested that the use of relative measures has not been adequately justified, because their use entails an arbitrary assumption: "Measurement by relative suppression presupposes that under constant experimental conditions the warning signal will produce the same relative decrement independent of the rate of responding at the moment of the warning signal presentation" (p. 68). It will be recalled (and will be discussed more fully in a later section) that the suppression measures of the present study gave no indication of the overall impaired avoidance of subjects during Phases 2 and 5.

Hurwitz and Roberts (1971) have suggested that relative frequencies of shocks during signalled and unsignalled periods are a more adequate measure of suppression of avoidance responding than relative frequencies of lever pressing. The results of the present study lend full support to this contention. Moreover, for an adequate analysis of behavior, relative measures must always be supplemented by absolute measures to aid in the interpretation of results. Finally, suppression ratios should not be used when the frequency of the measured events is very low.

Unconditioned suppression to the clicker stimulus.

Suppression occurred to the clicker regardless of whether or not it was followed by unavoidable shock and regardless of the temporal patterning of the clicker within a session. This was an unexpected finding which merits further investigation.

Many researchers in conditioned suppression (e.g., Estes and Skinner, 1961; Hurwitz and Roberts, 1971, Roberts and Hurwitz, 1970) seldom presented the signal unpaired with shock prior to the signal-shock pairing procedure, as they were interested primarily in terminal performance under signal-shock pairing. Others (e.g., Lolordo, 1968; Pomerleau, 1970; Riess and Bath, 1970) have presented the unpaired signal in the first phase and have found either no effect or a temporary effect followed by habituation to the signal. Lolordo (1968) developed a "truly random" procedure during which the probability of shock was the same both in the presence and absence of a 400 cps tone. The tone had no suppressive effects unless the probability of shock following the tone was higher than the probability of shock during other session time.

Some researchers (e.g., Davis, Memmott, and Hurwitz, 1976; Pomerleau, 1970;) presented the unpaired signal during the first three or four sessions to control for suppression to the signal alone. Suppression of avoidance responding was not obtained to either a clicker stimulus presented

alone (Davis et al., 1976) or to a visual signal (Pomerleau, 1970). It is notable, however, that in the first phase of the present experiment, suppression of shock avoidance during CPs did not occur immediately for three out of four subjects. For one subject it was after 4 sessions that avoidance suppression occurred. Another subject showed suppression after 8 sessions, and another after 16 sessions. Following these initial sessions, however, avoidance suppression during the clicker alone persisted for as many as 76 sessions.

Roberts and Hurwitz (1970) presented a "signal-alone" phase following a "signal-shock" phase to rats trained to respond under a free-operant avoidance schedule. The signal consisted of a relay pulsed at 10 per second (i.e., a clicker noise) which added 10db to the resting noise level of 80db. (Thus, the signal did not differ greatly from the 86db, 30 clicks per second of the present experiment.) They found that response rates during the signal remained considerably lower than pre-signal response rates. The avoidance schedule was suspended, however, during presentations of the signal in order to eliminate confounding of measures by response bursting following unavoided shocks. Although the suppressive effects of the signal on response rates may have been due to signal-shock pairing in the previous phase, results of the present experiment suggest that pairing unavoidable shock with the signal may not have been a necessary condition for obtaining reduction of avoidance responding.

There is some evidence that particular auditory stimuli are aversive without any prior pairing with shock. Lolordo (1967) used noise as an aversive stimulus, but his noise was 108db of a very short duration. (It is possible that lower intensities of sound, for instance, the 86db clicker of the present study, become aversive with longer presentations.) Myers (1965) found that rats will respond to escape buzzer presentations. In a conditioned suppression study, Hoffman (1969) obtained suppression of food-reinforced responding upon presentation of an 88db random noise, while the same subjects did not show reduced responding to a 1000 cps tone of 88db.

Perhaps more relevant to the present study was the finding (Riess, 1971) that one-minute buzzer presentations to rats responding on a free-operant avoidance schedule resulted in lever pressing suppression during the buzzer. Earlier, Riess (1970) had ruled out response changes being due to novel properties of the buzzer because two other novel stimuli were presented to subjects: removal of the masking noise and a 60db clicker, both of which failed to elicit any change at all. Riess stated that "aversive properties" of the buzzer were responsible for response changes and supported this contention by the informal observation that the predominant reaction of the subjects to the buzzer appeared to be "fear", as evidenced by increased defecation, respiration, and hyperactivity during the buzzer presentations. Riess (1970, p. 168) went on to say, with little

apparent evidence, that "the specific accoustic property properly responsible for the behavioral changes observed appeared to be the auditory variability per se or the number of intensity and frequency changes per unit time..."

Like Riess's buzzer, the 30 clicks per second of the present experiment had more variability than white noise or tones used in some other experiments (e.g., Lolordo, 1967). There is little evidence, however, to permit a specification of the stimulus properties of the clicker which were responsible for suppressed avoidance. The white noise in this study was of a similar intensity as the clicker, but all rats in most phases consistently avoided more shocks during the white noise than during the clicker (with the exception of subject 125H during the WNP-shock pairing of Phase 5). Moreover, by making the clicker noise the predominant auditory stimulus during Phases 4 to 6 (90 minutes of a 120-minute session) it might be expected that subjects would habituate to the clicker noise and suppress to the "novel" or less frequent stimulus. There was no evidence for this occurring in the present experiment.

In considering the suppressive effect of the clicker noise, it is interesting to note the results of Phase 5. Following WNPs with unavoidable shock resulted in impaired avoidance for all subjects during WNPs. That is, all subjects received relatively more shocks during WNPs in Phase 5 than they had received in Phase 4. The suppressive effects of WNP-shock pairings of Phase 5 were, however, for

three subjects, insufficient to overcome the suppressive effects of the clicker. Only one subject responded so as to receive more shocks during WNPs than during session time when the clicker noise was present.

Barrett (1975) has pointed out how attempts to describe the effects of environmental stimuli on behavior are often based on presumed inherent properties of the stimuli themselves. This seems to be particularly true of electric shock and such presumptions have been frequently applied to the results of studies using the Estes-Skinner procedure. It was mentioned in the introduction of this thesis that response reductions or acceleration have been explained in terms of conditioned "fear" or "anxiety" stemming from the presentation of electric shock. The "fear" or "anxiety" subtracts from motivation maintaining positively reinforced behavior and summates with motivation maintaining negatively reinforced behavior (Rescorla and Solomon, 1967). The present experiment suggests that characterizing response suppression or acceleration during a pre-shock stimulus in the Estes-Skinner procedure in terms of a conditioned emotional response such as "fear" or "anxiety" may be misleading.

Changes in operant response rates, often said to reflect an emotional state set up in anticipation of a disturbing stimulus (e.g., Estes and Skinner, 1941), do not necessarily occur exclusively as the result of signal-shock pairing.

In summary the present data indicate that the

presentation of at least one kind of response independent auditory stimulus can result in definite changes in behavior which may have been previously attributed to signal-shock pairing.[1]

Effects of signal-shock pairing.

The principal effect of signal-shock pairing was impaired avoidance throughout the session for all subjects. That is, more avoidable shocks were received per session by all subjects when the unavoidable shock contingency was introduced. Disruption of avoidance behavior occurred in Phase 2 when CPs were followed by shock and was clearly replicated in Phase 5 when WNPs were followed by shock. When the unavoidable shock contingency was removed in Phase 3 and 6, unavoidable shocks received by the subjects decreased, with one exception. Subject 154H received increasing numbers of shocks in successive phases of the experiment. During Phase 6 the number of avoidable shocks received by subject 154H was very high and this subject died shortly after the eighth session of Phase 6. It is possible, therefore, that abnormal physiological factors had begun to influence this subject's avoidance behavior.

Other investigators have also found that signal-shock pairing can exert powerful effects on baseline behavior. Seligman (1968) reported that positively reinforced rats which experienced a signal followed by shock showed

reduced baseline response rates during early sessions but gradually recovered their pre-shock baselines. Seligman and Meyer (1970) found no sign of recovery of food maintained baseline responding for up to 70 experimental sessions during which a signal and shock were randomly related.

Using a free-operant avoidance baseline, Hurwitz and Roberts (1971) found that signalled shock resulted in an overall increase in shock rates in non-signalled periods, with shock rates in signalled periods considerably greater than in non-signalled periods. In the present study similar results were obtained in Phase 2 for all subjects and in Phase 5 for one subject. Davis, Memmott, and Hurwitz (1976) obtained severe disruption of baseline rates of avoidance responding when a signal-shock procedure was imposed on the schedule. It seems, however, that investigators do not typically report changes in overall baseline rates when a signal-shock contingency is introduced (see reviews by Davis, 1968; Lyon, 1968).

It is interesting that, in spite of the increased shocks received per session, (and in spite of the fact that the rats were sensitive to the signal in that CPs alone produced suppression) the signal-shock pairing of Phase 2 did not appreciably affect the suppression ratios for avoidable shocks except in the case of subject 150H. Shock ratios for subject 150H temporarily decreased to below 0.50, indicating avoidance <u>facilitation</u> during the pre-shock clicker stimulus. After 12 sessions, however, this subject

exhibited suppression during CPs although there was little difference in ratio values from the previous phase. That is, addition of the unavoidable shock did not increase the suppressive effect of the CPs.

Lever-press ratios for all subjects showed temporary increases during Phase 2, perhaps because of more post-shock lever-press bursting during CPs. This possibility will be discussed in the next section.

The above notwithstanding, following each one-minute WNP with an unavoidable shock in Phase 5 did result in a change in suppression ratios. One subject, 125H, received more shocks during WNPs than during equal session time during which white noise was absent and the clicker was present. Although the shock ratios of other subjects increased slightly, the suppressive effects of unavoidable shock, as pointed out in the previous section, was evidently not sufficient to completely offset the suppressive effects of the clicker noise. That is to say, the suppression ratios for avoidable shocks, although showing increases over the previous phase for these three subjects, were still below 0.50 during Phase 5 when WNPs were followed with shock. Thus, there were still fewer shocks received during WNPs than during session time when the clicker noise was operative.

Why did suppression ratios for shock show no change in Phase 2, but show some changes in Phase 5? In Phase 5, unlike Phase 2, the unavoidable shocks were longer (1.0 sec)

than the avoidable shocks. Roberts and Hurwitz (1970) have reported that using relatively longer unavoidable shock facilitated the suppressive control by the signal over ongoing research rates. When the length of the unavoidable shock was increased in Phase 5, subject 125H exhibited marked avoidance suppression during WNPs. It is clear from this rat's decreased suppression ratios for shocks before and following Phase 5 that following WNPs with unavoidable shock was a necessary (though perhaps not sufficient) condition for suppression to occur during WNPs. Unavoidable shock was not a necessary condition for suppression to occur during CPs.

It is not clear why one subject showed such dramatic suppression during WNPs followed by unavoidable shock while the others did not. Blackman (1976), in a recent review of conditioned suppression, stated that suppression of avoidance behavior has occurred when the unavoidable shock is discriminable from avoidable shocks. Increasing the length of the shock, however, does more than increase its discrimination; presumably it makes it more aversive. Perhaps a greater increase in the length of unavoidable shock would have resulted in all subjects showing suppressed avoidance during WNPs.

In summary, the present results indicate that, when a signal-shock contingency is imposed on a free-operant avoidance baseline, disruption of avoidance behavior occurs. This disruption may or may not be greater during

signalled periods, depending on the stimulus used as the signal, on the length of unavoidable shock, and on other known and unknown variables. The impaired avoidance behavior is not, however, confined to the presence of the signal. More research is needed to determine the variables that contribute to avoidance suppression during a pre-shock stimulus in particular, and to avoidance suppression in general.

Post-shock response distributions.

Hurwitz and Roberts (1971) found that the introduction of signalled shock on an avoidance baseline resulted in an increase in avoidable shocks during the signalled periods. They found that increases in shock rate during the signal were not systematically related to changes in response rate. Subjects trained under high shock intensity (2.0 mA), which was the same intensity used in the present study, showed increased response rates. The authors hypothesized that the increases may have been due to response bursts elicited by unavoided shocks, but they had no measures to support this hypothesis. The response-rate distributions of the present experiment support Hurwitz and Roberts' suggestion that post-shock response bursts can and do inflate the response rate values during the signal in conditioned suppression studies.

All subjects showed lever-press and lever-bite

response bursting in the first two-second interval following shock during most phases of the present experiment. (The exceptions to this statement are found in the response distributions of rat 154H during Phases 1 and 4). As was discussed earlier, all subjects also received more avoidable shocks during the clicker stimulus. Although the rate distribution data did not reflect consistently higher rates of responding during CPs relative to other session time, it must be recalled that this data reflect responses per avoidable shock. Therefore, if more shocks occurred during the clicker, and shocks were followed by response bursting, it follows that there was relatively more response bursting during the clicker.

Although there was only one lever-press measure during the present experiment, post-shock response-rate distributions provide evidence that lever-press frequencies must be considered an additive function of two different response components: (1) elicited lever attacking and, (2) operant avoidance responding. Lever biting appeared to be elicited by shock because these responses occurred during and immediately following shock and did not occur in later time intervals following shock, as did lever pressing. This pattern is similar to that observed during shock elicited aggression (Azrin et al., 1964; Azrin et al., 1968), and thus supports the contention that post-shock bursting of lever biting is attributable, at least in part, to elicited respondent components. Lever-press bursting in

the first interval following shock was closely correlated with post-shock lever biting, and therefore, also seems attributable, at least in part, to elicited respondent components. Consequently, not all lever pressing can be considered avoidance responding.

It seems that the distribution of responses following shock is an important determinant of function. It is quite understandable that a lever-press response emitted immediately following shock contributes very little to avoiding the subsequent shock. While responding during the first interval following shock is considered to consist of elicited lever attacking (McLean, 1975), responding during later intervals following shock may be assumed to be largely operant avoidance responding. (This assumes that little elicited biting occurs in later intervals after shock, which is consistent with studies cited previously on elicited attack.) Subject 130H avoided the fewest shocks of all subjects. The rate distribution data show very low rates of responding in later intervals after shock for this subject (see Figure 3). On the other hand, subject 150H avoided all but a few shocks per session. Rate distribution data show that this subject responded at higher rates in later intervals following shock than did the other subjects.

Response-rate distributions also frequently show decreased response bursting in the first post-shock interval and increased lever-press responding during later post-

shock intervals when avoidable shocks received per session decreased. When response-rate distributions for Phases 2 and 3 are compared (see Figures 4 and 5), it can be seen that rates of responding in later intervals following shock are higher in Phase 3 than in Phase 2. Responding in later intervals in Phase 3 increased as more shocks were avoided.

To illustrate further, when responding in the first interval following shock is discounted as being elicited lever attacking which contributes little to shock avoidance, a decrease in avoidance responding can be seen from Phases 4 to 5 (compare Figures 6 and 7) for subjects 125H, 130H, and 154H. That is, the increased number of avoidable shocks received by the subjects during Phase 5 is reflected by increased pressing and biting in the first interval following shock and decreased lever pressing in later intervals following shock.

An examination of the rate distributions of subjects 150H and 154H (see Figure 3, for example) indicate that there was frequently an increase in rates of lever-press responding during later intervals following shock, which corresponded to the length of the S-S interval (10 seconds) or the R-S interval (20 seconds). Subject 150H avoided most shocks and rarely experienced the S-S interval. This subject frequently showed an increased rate during the 20 second interval: the length of the R-S interval. This increase may have been due to a temporal discrimination based on time since the last shock delivery. On the other

hand, subject 154H showed increased rates during the 8 and 10 second intervals following shock. Subject 154H received many more shocks than subject 150H, frequently experienced the S-S interval, and possibly made a temporal discrimination based on the S-S interval.

The response-rate distribution data for subject 154H is quite different from the response-rate distribution data of the other subjects and provide no easy interpretation. Subject 154H lever-pressed at a very low rate in all post-shock intervals and seldom bit the lever. In spite of this low rate of responding this subject avoided as many shocks as rat 125H, and avoided more shocks than subject 130H. These two subjects, however, responded at higher rates than rat 154H following shock, indicating that much of the lever-press responding they exhibited was "inefficient"; that is, contributed little to shock avoidance.

Subject 154H exhibited post-shock bursting for the first time during Phase 5, although response rates were still much lower than the rates of the other subjects. It is interesting that this subject's post-shock bursting, when it occurred, took the form of both lever-pressing and biting. This result is consistent with McLean's (1975) finding that lever-press bursting was exhibited only by subjects that demonstrated lever-bite bursting, and supports the contention that lever pressing in the first post-shock interval consists of elicited behavior.

In conclusion, the response-rate distributions

qualify and extend the suppression ratio data of the present experiment by reflecting the contributions of operant and elicited responding in measures of suppression. The suggestion by Hurwitz et al., (1971) that suppression ratios based on response rates are inflated due to post-shock lever-press bursting has been given quantitative support. Subtle changes in moment-to-moment rates of responding during post-shock intervals within and across phases permit no easy interpretation, although some consistencies are apparent.

Summary of main conclusions.

On the basis of the data from this study, the following conclusions can be drawn:

1. (a) Rats responding on a free-operant avoidance schedule may show suppression of avoidance behavior during presentations of an auditory stimulus, regardless of whether it is paired with shock. Moreover, the suppression may not occur immediately, but may be apparent only after several sessions.

(b) Unconditioned suppression during an auditory stimulus may be very persistent. In the present study, avoidance suppression during the clicker alone (i.e., unpaired with unavoidable shock) was maintained for as many as 76 120-minute sessions.

(c) Avoidance suppression may occur to a

clicker stimulus regardless of its temporal position or duration in an experimental session. The results of the present study show that avoidance suppression was obtained during the clicker whether the clicker occurred 30 times for one minute each, or for 90 minutes of a 120-minute session.

2. Relative frequencies of avoidable shocks during signalled and unsignalled periods are a more adequate measure of suppressed avoidance responding than relative frequencies of lever pressing. In the present study, lever-press frequencies consisted of both elicited response bursts following shock, which were correlated with lever biting, and operant avoidance responses. The measure of suppressed avoidance responding was spuriously inflated by the increase in lever-press response bursting as the subjects received more shocks during the clicker.

3. Suppression ratios based on operandum attacking (e.g., lever biting in the present study) are closely correlated with suppression ratios for shocks.

4. Post-shock lever-press and lever-bite rate distributions may reflect the contributions of both operant and elicited responding to measures of avoidance.

5. When a stimulus signals unavoidable shock, disruption of avoidance behavior throughout the session is observed. The suppressive effects of signal-shock pairings are not confined to the presence of the signal.

(a) When an unavoidable shock of the same

duration as the avoidable shock follows the signal, avoidance suppression throughout the session may be accompanied by little or no change in suppression ratios.

(b) When an unavoidable shock of longer duration than the avoidable shock follows the signal, avoidance suppression throughout the session may be accompanied by changes in relative frequencies of shocks before and during the signal, as indicated by changes in suppression ratios.

6. Previous explanations of the Estes-Skinner procedure in terms of "anxiety" or a "conditioned emotional response" being elicited by the signal as a result of signal-shock pairing may have been misleading. In the present study, pairing of a signal with shock was not a necessary condition for suppression to occur. Avoidance suppression can not be explained as the result of the rats "anticipating" an aversive event. Changes in behavior during an auditory stimulus occurred prior to any specific conditioning of "fear" or "anxiety" to that stimulus.

REFERENCES

Azrin, N.H. and Hake, D.F. Positive conditioned suppression: Conditioned suppression using positive reinforcers as the conditioned stimuli. Journal of the Experimental Analysis of Behavior, 1969, 12, 167-173.

Azrin, N.H., Hutchinson, R.R. and Hake, D.F. Pain induced fighting in the squirrel monkey. Journal of the Experimental Analysis of Behavior, 1963, 6, 620-621.

Azrin, N.H., Hutchinson, R.R. and Sallery, R.D. Pain aggression toward inanimate objects. Journal of the Experimental Analysis of Behavior, 1964, 7, 223-227.

Azrin, N.H., Rubin, H.B. and Hutchinson, R.R. Biting attack by rats in response to aversive shock. Journal of the Experimental Analysis of Behavior, 1968, 11, 633-639.

Barrett, J.E. The Estes-Skinner procedure: Inadequacy of traditional interpretations. The Psychological Record, 1975, 25, 167-172.

Belleville, R.E., Rohles, F.H., Grunzke, M.C. and Clark, F.D. Development of a complex multiple schedule in the chimpanzee. Journal of the Experimental Analysis of Behavior, 1963, 6, 549-556.

Blackman, D.E. Conditioned suppression or facilitation as a function of the behavioral baseline. Journal of the Experimental Analysis of Behavior, 1968, 11, 53-61.

Blackman, D.E. Conditioned suppression and the effects of classical conditioning on operant behavior. In W. K. Honig and J.E.R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs: Prentice-Hall, 1977.

Bolles, R.C. Species - specific defense reactions. In F.R. Brush (Ed.), Aversive Conditioning and Learning. New York: Academic Press, 1971.

Boren, J.J. Isolation of post-shock responding in a free-operant avoidance procedure. Psychological Reports, 1961, 9, 265-266.

Brady, J.V., Kelly, D. and Plumlee, L. Autonomic and behavioral responses of the rhesus monkey to emotional conditioning. Paper presented at the third annual convention of the Midwest Association of Behavioral Analysis, Chicago, 1977.

Bryant, R.C. Conditioned suppression of free-operant avoidance. Journal of the Experimental Analysis of Behavior, 1972, 17, 257-260.

Davis, H. Conditioned suppression: A survey of the literature. Psychonomic Monograph Supplements, 1968, 2, 283-291.

Estes, W.K. Outline of a theory of punishment. In B.A. Campbell and R.M. Church (Eds.), Punishment and Aversive Behavior. New York: Appleton-Century-Crofts, 1969.

Estes, W.K. and Skinner, B.F. Some quantitative properties of anxiety. Journal of Experimental Psychology, 1941, 29, 390-400.

Grossen, N.E. and Bolles, R.C. Effects of a classical conditioned 'fear signal' and 'safety signal' on non-discriminated avoidance behavior. Psychonomic Science, 1968, 11, 321-322.

Herrnstein, R.J. Method and theory in the study of avoidance. Psychological Review, 1969, 76, 49-69.

Hoffman, H.S. Stimulus factors in conditioned suppression. In Campbell, B.A. and Church, R.M. (Eds.), Punishment and Aversive Behavior. New York: Appleton-Century-Crofts, 1969, 185-234.

Hunt, H.F. and Brady, J.V. Some effects of electro-convulsive shock on a conditioned emotional response ("anxiety"). Journal of Comparative and Physiological Psychology, 1951, 44, 88-98.

Hurwitz, H.M.B and Bounds, W. Response specification and acquisition of free-operant avoidance. Psychological Reports, 1968, 23, 483-494.

Hurwitz, H.M.B. and Roberts, A.E. Conditioned suppression of an avoidance response. Journal of the Experimental Analysis of Behavior, 1971, 16, 275-281.

Hutchinson, R.R., Azrin, N.H. and Hake, D.F. Attack, avoidance, and escape reactions to aversive shock, Journal of the Experimental Analysis of Behavior, 1967, 10, 131-148.

Kamin, L.J. Temporal and intensity characteristics in the conditioned stimulus. In W.F. Prokasy (Ed.), Classical Conditioning: A Symposium. New York: Appleton-Century-Crofts, 1965, 118-147.

Keller, F.S. Light-aversion in the white rat. Psychological Record, 1941, 4, 235-250.

Konorski, J. Integrative Activity of the Brain. Chicago: University of Chicago Press, 1967.

Lyon, D.O. Conditioned suppression: Operant variables and aversive control. Psychological Record, 1968, 18, 317-338.

Malott, R.W., Sidley, N.A. and Schoenfeld, W.N. Effects of separate and joint escape and avoidance contingencies. Psychological Reports, 1963, 13, 367-371.

McLean, L.L. Post-shock bursting and lever attacking under various schedules of shock presentation. (Masters thesis, University of Manitoba, 1975).

Meltzer, D. and Brahlek, J.A. Conditioned suppression and conditioned enhancement with the same positive UCS: An effect of CS duration. Journal of the Experimental Analysis of Behavior, 1970, 13, 67-73.

Micziek, K.A. and Grossman, S. Positive conditioned suppression: Effects of CS duration. Journal of the Experimental Analysis of Behavior, 1971, 15, 243-247.

Myers, A.K. Instrumental escape conditioning to a low-intensity noise by rats. Journal of Comparative and Physiological Psychology, 1965, 66, 82-87.

Pear, J.J. and Hemingway, M.J. Lever attacking and pressing as a function of conditioning and extinction of a lever-press avoidance response in rats. Paper presented at the meeting of the Canadian Psychological Association, Victoria, British Columbia, June, 1973.

Pear, J.J., Moody, J.E. and Persinger, M.A. Lever attacking by rats during free-operant avoidance. Journal of the Experimental Analysis of Behavior, 1972, 18, 517-523.

Pomerleau, O.F. The effects of stimuli followed by response-independent shock on shock-avoidance behavior. Journal of the Experimental Analysis of Behavior, 1970, 14, 11-21.

Powell, R.W. Some effects of response-independent shocks after unsignalled avoidance conditioning in rats. Learning and Motivation, 1972, 3, 420-441.

Powell, R.W. and Peck, S. Persistent shock-elicited responding engendered by negative reinforcement procedure. Journal of the Experimental Analysis of Behavior, 1969, 12, 1049-1062.

Rescorla, R.A. and Lolordo, V.M. Inhibition of avoidance behavior. Journal of Comparative and Physiological Psychology, 1965, 59, 400-412.

Rescorla, R.A. and Solomon, R. Two-process learning theory: Relationships between Pavlovian conditioning and instrumental learning. Psychological Review, 1967, 74, 151-182.

Riess, D. The buzzer as a primary aversive stimulus: Unconditioned acceleration and summation of conditioned and unconditioned acceleration. Psychonomic Science, 1970a, 21, 167-169.

Riess, D. The buzzer as a primary aversive stimulus: Unconditioned and conditioned suppression of barpress avoidance. Psychonomic Science, 1971, 24, 212-214.

Riess, D. and Bath, J. Operant and Pavlovian stimulus control of avoidance latencies in conditioned acceleration. Psychonomic Science, 1970, 19, 165-167.

Roberts, A.E. and Hurwitz, H.M.B. The effects of a pre-shock signal on a free-operant avoidance response. Journal of the Experimental Analysis of Behavior, 1970, 14, 331-340.

Seligman, M.E.P. Chronic fear produced by unpredictable eletric shock. Journal of Comparative and Physiological Psychology, 1968, 72, 546-550.

Seligman, M.E.P. On the generality of the laws of learning. Psychological Review, 1970, 77, 406-418.

Seligman, M.E.P. and Meyer, B. Chronic fear and ulceration in rats as a function of unpredictability of safety. Journal of Comparative and Physiological Psychology, 1970, 73, 202-207.

Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning stimulus. Science, 1953, 157-158.

Sidman, M. Some properties of the warning stimulus in avoidance behavior. Journal of Comparative Physiological and Psychology, 1955, 48, 444-450.

Sidman, M. Some notes on "bursts" in free-operant avoidance experiments. Journal of the Experimental Analysis of Behavior, 1958, 1, 167-172.

Sidman, M., Herrnstein, R.J., and Conrad, R.G. Maintenance of avoidance behavior by unavoidable shocks. Journal of Comparative and Physiological Psychology, 1957, 50, 553-557.

Skinner, B.F. Science and human behavior. New York: Appleton, 1953.

Smith, J.B. Effects of response rate, reinforcement frequency, and the duration of a stimulus preceeding response-independent food. Journal of the Experimental Analysis of Behavior, 1974, 21, 215-221.

Ulrich, R.E. Pain as a cause of aggression. American Zoologist, 1966, 6, 643-662.

Ulrich, R.E. and Azrin, N.H. Reflexive fighting in response to aversive stimulation. Journal of the Experimental Analysis of Behavior, 1962, 5, 511-520.

Ulrich, R.E. and Craine, W.H. Behavior: Persistence of shock induced aggression. Science, 1964, 143,

Waller, M.B. and Waller, P.F. The effects of unavoidable shocks on a multiple schedule having an avoidance component. Journal of the Experimental Analysis of Behavior, 1963, 6, 29-37.

FOOTNOTE

1. A potential alternative interpretation for the avoidance suppression to the clicker involves a conditioned rather than an unconditioned mechanism. Since the clicker presentation coincided with the onset of avoidance training, a large number of clicker-shock pairings could have occurred due to the non-avoidance of shock. The consequence of the inadvertent pairing might be the gradual increase in avoidable shock received during the clicker in Phase 1. (Thanks go to Dr. Robert Tait for suggesting this possibility)