MAINTENANCE AND SUPPRESSION OF RESPONDING UNDER CONCURRENT SCHEDULES OF ELECTRIC-SHOCK PRESENTATION

By

FRANK MICHAEL WEBBE

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PREFACE

The experiments reported here represent the combined endeavor of persons involved in the operations of the Operant Behavior Laboratory at the University of Florida. As my name on the title indicates, I have borne the daily responsibility of experimentation and supervision, as well as the onus of textual composition. However, the experiments and many of the ideas reported here were germinated in an atmosphere of scholarly and experimental inquiry of which I was a part.

The science of behavior has passed the point wherein any one person bears full responsibility for the creation and implementation of experimental ideas. Without the work of previous investigators, and without the individual contributions of those who shared in this study, the endeavor never would have been accomplished.

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Frank Michael Webbe

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Following a variety of experimental histories, squirrel monkeys continue to respond under conditions in which schedules of electric-shock presentation remain as the only programmed consequences of responding. The rates and patterns of responding are similar to those that ordinarily characterize responding under similar schedules of food or water presentation.

The experiments reported here were concerned with investigating further the conditions under which this phenomenon might occur. Specifically, squirrel monkeys were trained first to respond under variable-interval (VI) schedules of shock presentation. Subsequently, concurrent variable-interval schedules were introduced. That is, the experimental chamber contained two levers, and schedules of shock presentation were programmed for responding on each lever.

Two basic procedures were employed for developing concurrent responding. In one procedure, the response lever was either in the

right or the left hand position during each of the last 60 sessions under a 3-min variable-interval (VI 3) schedule of shock presentation. Subsequently, two levers were inserted into the chamber at the same time, and equal and independent VI 3 schedules were programmed for responding on each lever. A bi-directional changeover delay was programmed such that changeover responses initiated a 0.50-sec interval during which programmed shocks could not be delivered.

In the second basic procedure, concurrent avoidance schedules were introduced following 107 sessions under a VI 3 schedule of shock presentation. Two levers were inserted into the chamber, and concurrent and independent 5-sec shock - shock intervals were programmed, as were concurrent and independent 30-sec response - shock intervals. Concurrent variable-interval schedules were introduced 30 sessions later.

After exposure to one of these training histories, the two monkeys continued to respond under several parameter values of the concurrent VI, VI schedules of electric-shock presentation. Both monkeys responded at higher rates on one lever than on the other. Responding on each lever was constant in rate, similar to the patterns usually maintained by comparable schedules of food or water presentation.

Following a minimum of 70 sessions under concurrent VI, VI schedules, the schedule for one of the levers was changed to extinction; that is, programmed shocks were no longer delivered as a consequence of responding on that lever. The VI 3 schedule remained in effect on the other lever. Under these conditions, responding on both levers decreased to zero rates. Similar results were obtained with both of the monkeys in two separate phases in which extinction was programmed

first on the left lever and then on the right lever.

In summary, two separate operants were acquired and subsequently maintained under VI, and concurrent VI schedules of electric-shock presentation. The rates and patterns of responding were comparable to those observed under similar schedules of food or water presentation. When one of the concurrent operants no longer produced shocks, responding decreased to zero rates, first on the lever for which shocks were still programmed, and subsequently on the lever for which no consequence was programmed. These results are exactly opposite to the effects of a comparable manipulation during concurrent responding under schedules of food or water presentation. The results indicate the necessity of further study of the response-produced shock phenomenon in complex situations. The generality of the phenomenon may be limited to situations providing no alternative responses with qualitatively different consequences.

INTRODUCTION

Since 1966, more than 10 studies have reported on the development and chronic maintenance of responding under schedules of electric-shock presentation. After initial histories of responding under schedules of food presentation, shock postponement, or shock termination, the occasional presentation of intense electric shocks remained as the only programmed consequences of responding. These studies have progressed in complexity from "simple" demonstrations of the phenomenon under fixed-interval (FI) schedules with squirrel monkeys (Kelleher and Morse, 1968; McKearney, 1968; Stretch, Orloff, and Dalrymple, 1968) and with cats (Byrd, 1969), to maintenance conditions under fixed-ratio (FR) schedules (McKearney, 1970) and variable-interval (VI) schedules (McKearney, 1972). More complex behavioral processes have also been investigated using this phenomenon, including extinction and recovery of responding (Kelleher and Morse, 1968; McKearney, 1969), the effects of interrupting behavior maintained under FI schedules by alternating S^D and S-delta periods (Stretch, Orloff, and Gerber, 1970), stimulus and schedule control during multiple schedules (McKearney, 1970, 1972), the establishment of second-order schedules of brief stimulus presentations (Byrd, 1972), examination of the effects of the Estes-Skinner procedure (McKearney, 1972), and the generation of schedule-induced hose-biting during FI schedules (Malagodi, DeNeese, Webbe, and Palermo, 1973).

In each of these reports, the patterns of behavior maintained

under schedules of shock presentation (other than FR 1) have been comparable to the patterns maintained under similar schedules of food or water presentation. By increasing the complexity of the experimental situation, each succeeding study has allowed for the further generalization of the conditions under which the presentation of response-dependent electric shocks will maintain behavior.

The series of experiments reported here were similarly concerned with extending the generality of conditions of behavior maintenance by response-dependent shock presentations. The experiments proceeded in three stages. First was the development and chronic maintenance of behavior under variable-interval schedules of electric-shock presentation. The second stage was the development of concurrent operants, each maintained by independent variable-interval schedules of shock presentation. The third stage was an examination of the effects upon rates and patterns of concurrent responding of changing one of the concurrent schedules - specifically, changing from a VI schedule to extinction.

EXPERIMENT I. DEVELOPMENT AND MAINTENANCE OF RESPONDING UNDER VARIABLE-INTERVAL SCHEDULES OF ELECTRIC-SHOCK PRESENTATION

McKearney (1972) reported the development and chronic maintenance of responding in two monkeys under variable-interval (VI) schedules of electric-shock presentation. The two monkeys had histories of exposure to shock-postponement and FI schedules of shock presentation. Seven sessions of shock-postponement training immediately preceded introduction of a 3-min variable-interval (VI 3) schedule of shock presentation. After a total of 33 sessions under VI 3, response rates had stabilized at higher values than were occurring for the sessions of shock postponement. Similar patterns of responding occurred during shock postponement and VI 3 conditions. That is, the steady rates characteristic of the two types of schedules were maintained throughout each session.

Experiment I was essentially a direct replication of McKearney's procedures. The only significant methodological departure in the present study was the alternation of the lever position (either on the left or right side of the front wall) from session to session. This manipulation was performed in anticipation of developing concurrent responding in Experiment II.

Method

Subjects

Two adult, male, jungle-born squirrel monkeys (*Saimiri sciureus*) were used. The monkeys were housed in individual cages with food and

water continuously available. Both monkeys were maintained at their free-feeding weights, about 1,000 g. A 12-hr light-dark cycle was maintained in the colony room, and experimental sessions occurred during the first quarter of the light cycle. The two monkeys had histories of responding under shock postponement and Fl schedules of shock presentation.

Apparatus

A Plexiglas chair similar to that described by Hake and Azrin (1963) was used. The monkeys were restrained only at the waist, with no restrictions placed upon movements of the upper torso, arms, neck, and head. The tail was confined in a non-conductive brass clamp and Plexiglas stock. Electric shock (6 mA for 100 msec) was delivered by a BRS-Foringer ac shock generator (BRS SG-901) to two brass electrodes resting on a shaved portion of the tail. A non-corrosive electrode cream (Grass, Inc., EC-2) was applied to the tail prior to each session to maintain a low electrical resistance between the electrodes and the tail.

The front wall of the chamber could be fitted with one or two Lehigh Valley rat levers (LVE #1352). The lever receptacles were located on the left and right side of the front wall, 6 cm above the waistplate and 8 cm apart. Lever depressions with a force in excess of 20 g (0.20 N) produced a loud click from a feedback relay mounted behind the front wall. Two yellow 7-w stimulus lamps and a 4-ohm speaker were mounted at the top of the front wall, 42.5 cm above the waistplate.

The entire experimental chamber was housed within a ventilated, sound-attenuating exterior chamber. A Plexiglas viewing port in the exterior chamber allowed continuous observations of experimental

sessions *via* closed-circuit television equipment. Standard electromechanical scheduling and recording devices were located in an adjoining room.

Procedure

The two monkeys, SM-38 and SM-432, had previously responded under FI schedules of electric-shock presentation for more than 150 sessions. During these sessions the response lever was always located on the left side of the front wall.

The first experimental condition of the present study was exposure to shock-postponement schedules (Sidman, 1953). In the presence of white noise and illumination of the yellow stimulus lamps, shocks were scheduled to occur every 5 sec (S - S = 5 sec). Each effective lever press postponed the next scheduled shock for 20 sec (R - S = 20 sec). With Monkey SM-38, the lever was located in the left position, while with Monkey SM-432, the lever position (right or left) was alternated randomly from session to session.

After 15 days of training, the shock-avoidance procedure was discontinued, and a 3-min variable-interval (VI 3) schedule of shock presentation was introduced. Under this condition, shocks no longer occurred in the absence of responding, but rather, the first response after an average of 3 min produced shocks. The film tapes scheduling the times when shocks could be produced were derived from Fleshler and Hoffman's (1962) equal-probability distribution of intervals. Individual intervals ranged from 5 sec to 12 min.

With both monkeys, the lever position was changed randomly to either the left or right side of the front wall during the 60 sessions of exposure to VI 3. Experimental sessions were conducted 6 days per

week, lasted for 60 min, and were preceded and terminated by 4-min periods of timeout (TO). The yellow lights and white noise were off during TO, and a low frequency clicking noise was present. Lever presses during TO had no programmed consequences, and shocks were never presented.

Results

Figure 1 shows cumulative records from the last session of shock avoidance, and from the 5th and 55th sessions of VI 3 for Monkey SM-38. Avoidance responding was characterized by steady rates at about 10 per min as is shown in Record A. Typically, 1 to 6 shocks per hour were delivered. Introduction of the VI 3 schedule of shock presentation resulted in an immediate increase in response rates to more than 20 per min, and in increase in shock rates to an average of 20 per hour (Record B). Characteristic steady rates of responding were maintained throughout the sessions. By the end of the 60-session phase, response rates had increased to about 30 per min, as is depicted in Record C.

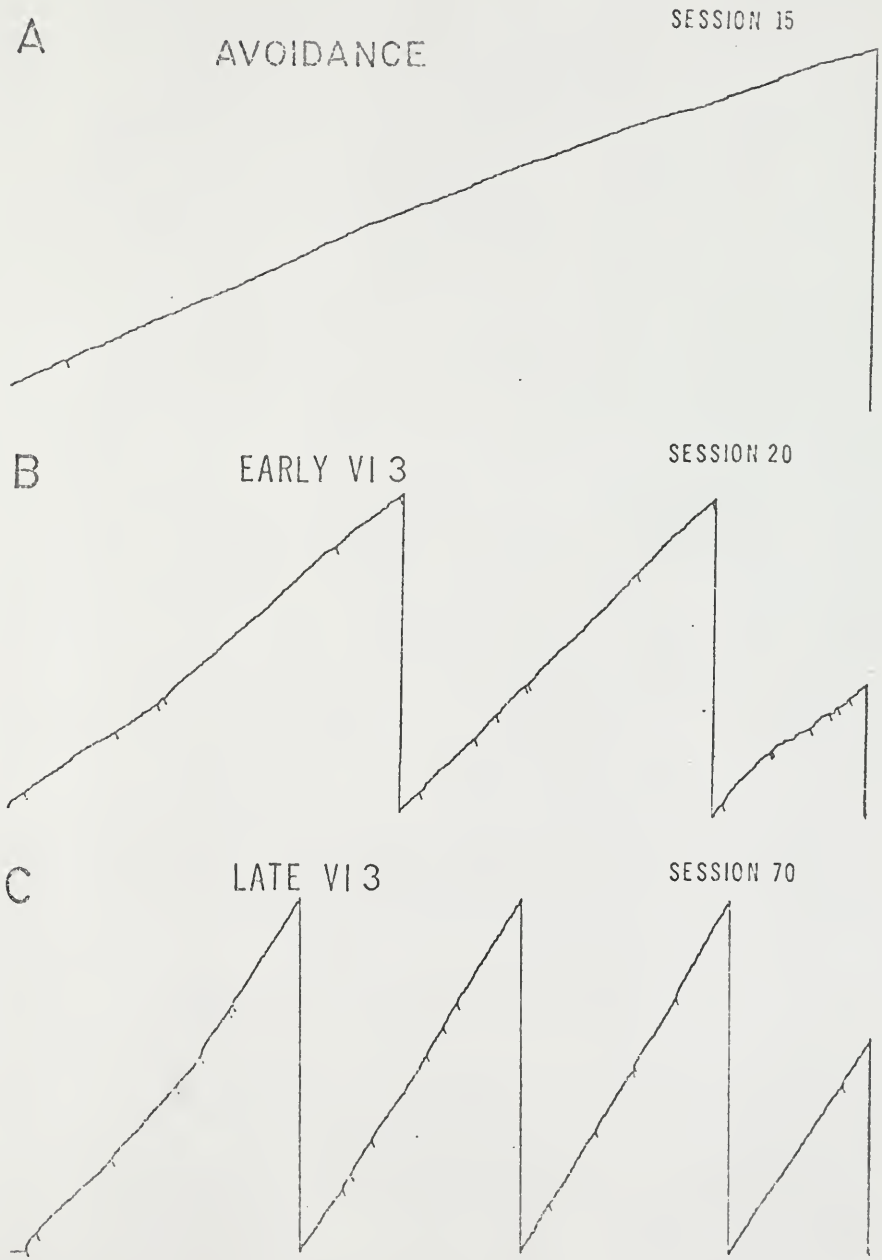
Similar results were obtained with Monkey SM-432. Avoidance responding was maintained at steady rates of 10 responses per min, with 1 or 2 shocks per hour delivered. Introduction of the VI 3 schedule resulted in marked increases in response rates, with an average of 20 shocks per hour being produced. Constant rates of more than 30 responses per min characterized performance after 60 sessions.

Effects of Changing Lever Position

Figures 2 and 3 show response rates and shock rates for Monkeys SM-38 and SM-432, respectively, during the last 10 sessions of avoidance and during the 60 sessions of VI 3. With SM-38, the lever was in the

Figure 1. Representative cumulative records for Monkey SM-38 showing final performance under the avoidance schedule, and early and late stages in the development of responding under the VI 3 schedule of shock presentation.

SM-38


A
AVOIDANCE
SESSION 15
B
EARLY VI 3
SESSION 20
C
LATE VI 3
SESSION 70

left position during all sessions of avoidance and during the first 10 sessions of VI 3. The initial effects of changing to the right position were overall decreases in response rates. Additionally, response rates were lower when the lever was on the right side than when it was on the left side. These differential rates persisted for about 9 sessions. Gradually, over a period of about 40 sessions, response rates increased from less than 10 per min to more than 25 per min. During the last several sessions, response rates were higher when the lever was on the right side than when it was on the left side.

With SM-432, the lever position was alternated randomly from side to side beginning with the 4th session of avoidance. Approximately equivalent rates were obtained regardless of lever position during all sessions of avoidance and the first 50 sessions of VI 3. Higher response rates occurred when the lever was on the right side during the last 10 sessions of VI 3.

Discussion

Characteristic steady rates of responding were maintained by the VI schedules of electric-shock presentation. In all respects, the behavior was similar to that reported by McKearney (1972). The chronic maintenance of characteristic response patterns with VI schedules of shock presentation also complements results obtained with FI (e.g., Kelleher and Morse, 1968) and FR schedules (McKearney, 1970).

Eubanks, Killeen, and Hamilton (1973) reported a failure to maintain lever pressing in squirrel monkeys under VI schedules of electric-shock presentation when each shock was not followed by a period of timeout from the experimental contingencies. The behavior was well maintained when 10- to 150-sec TOs followed each shock under VI 2.

Figure 2. Response rates and shock rates for Monkey SM-38 during 70 consecutive sessions of shock avoidance and a 3-min variable-interval schedule of shock presentation. Open symbols indicate sessions when the lever was in the right position; filled symbols indicate sessions when the lever was in the left position.

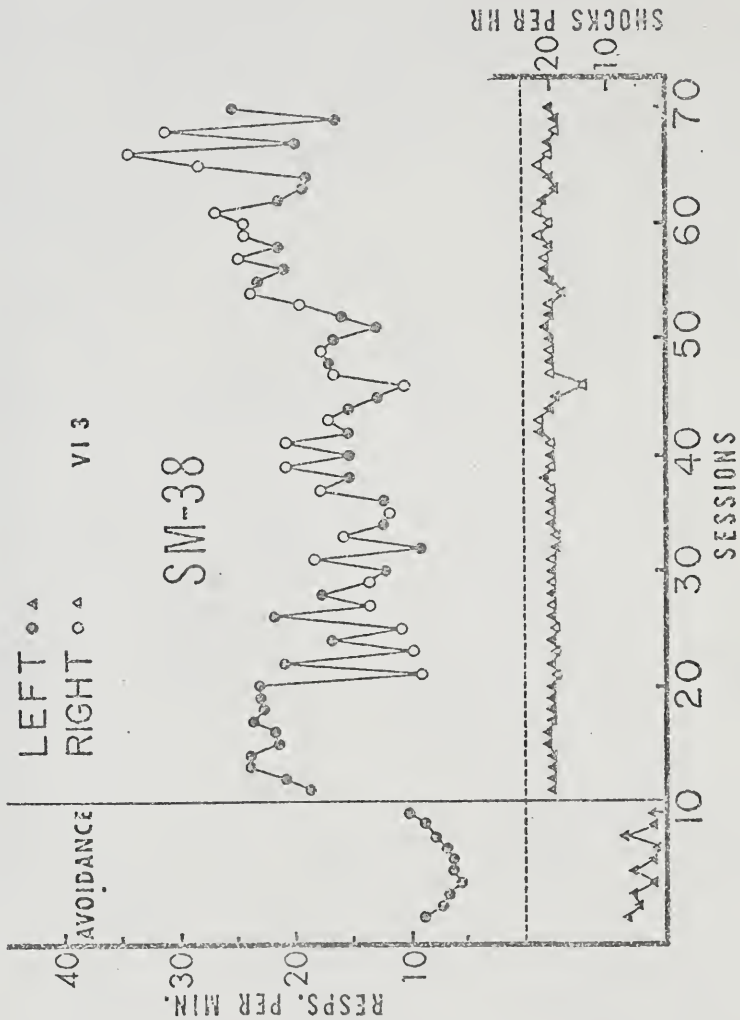
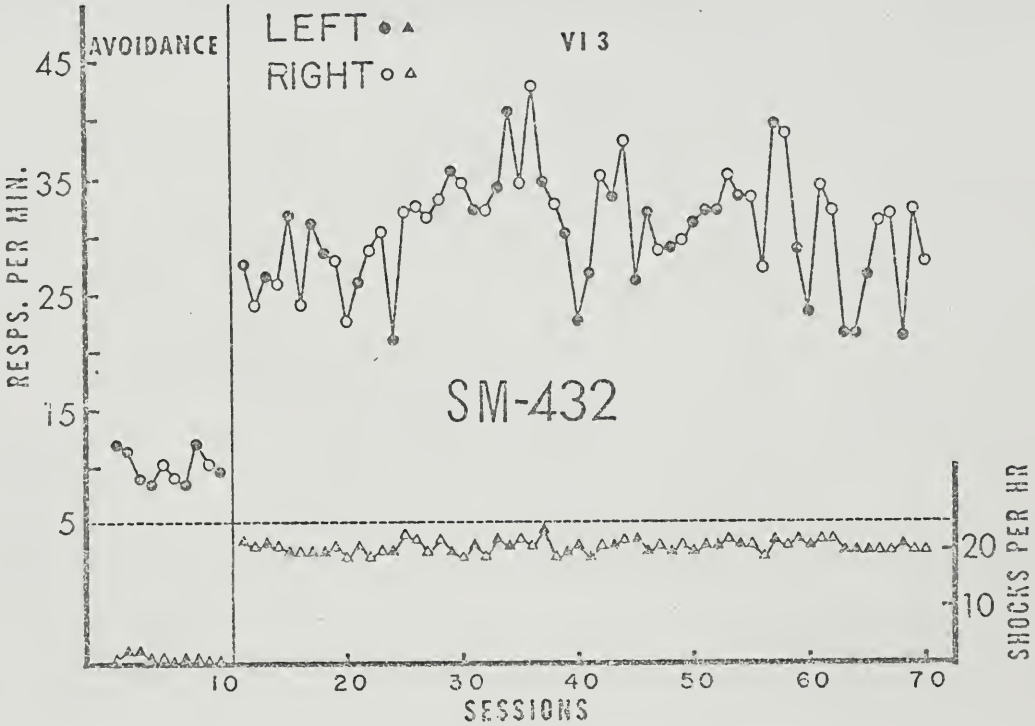

LEFT
RIGHT
VI 3
SM-38
AVOIDANCE
RESPS. PER MIN.
40
30
20
10
SHOCKS PER HR
20
10
SESSIONS
10
20
30
40
50
60
70

Figure 3. Response rates and shock rates for Monkey SM-432 during 70 consecutive sessions of shock avoidance and a 3-min variable-interval schedule of shock presentation. Open symbols indicate sessions when the lever was in the right position; filled symbols indicate sessions when the lever was in the left position.


AVOIDANCE
LEFT
RIGHT
VI 3
SM-432
RESPS. PER MIN.
45
35
25
15
5
SHOCKS PER HR
20
10
10
20
30
40
50
60
70
SESSIONS

Responding rapidly decreased to low rates and was not maintained when the TOs were discontinued. In comparing their results to those obtained by McKearney (1972), Eubanks et al. suggested that differences in the method of derivation of the VI schedules might have accounted for the disparity in results. McKearney used an arithmetic distribution of intervals, while Eubanks et al. used a constant-probability distribution. Although each interval occurs with a fixed relative frequency in both types of distributions, the increasing probability of shocks as a function of the passage of time since the last shock is more readily discriminable in an arithmetic distribution (cf., Fleshler and Hoffman, 1962). Moreover, the probability of shocks following shocks closely in time is lower with an arithmetic distribution than with an equal- or constant-probability distribution. Accordingly, Eubanks et al. raised the possibility that an implicit TO following shocks might have been present in McKearney's experiment. This possibility, in combination with their own failure to maintain behavior without TOs (using a constant-probability distribution), led Eubanks et al. to suggest that timeout following shock may be a necessary condition for the maintenance of behavior under VI schedules of electric-shock presentation. However, in the present study, a constant-probability distribution of intervals was always used, TOs were never scheduled following shocks, and the behavior was well maintained.

The present results with respect to changing lever positions may bear upon the failure to maintain behavior that was reported by Eubanks et al. With Monkey SM-432, the new lever position was introduced before the introduction of the VI schedule of shock presentation.

Even in the early sessions of VI 3, characteristic rates and patterns of responding occurred regardless of the lever position. With Monkey SM-38, however, introducing the new lever position during the 11th session of VI 3 resulted in marked decreases in response rates. Additionally, the steady-rate patterns of responding were disrupted, such that oscillations between high and low response rates occurred. This disruption in rates and patterns of responding was not limited to those sessions when the lever was in the new (right) position, but also occurred during sessions when the lever was in the original (left) position. The behavior gradually recovered from low to high maintained rates of responding over a number of sessions.

The effects of disrupting behavior maintained by schedules of shock presentation has been discussed previously by Morse and Kelleher (1970). The behavior is characterized by the interaction of stereotyped, ongoing behavior patterns with the schedule of shock presentation. Any intervention which disrupts the patterning results in a change in the temporal relationships and dynamic interactions between responding and shock presentation. Depending upon the severity of the disruption, similar, or new and different stable patterns may develop and be maintained. For example, in the present experiment, the steady, moderate rates of avoidance responding interacted with the VI schedule of shock presentation such that the patterns of responding remained the same, although response rates increased. The monkeys responded at the same steady rates both before and after shock presentations. The introduction of the novel lever position resulted in a decreased rate of responding for the one monkey, but the patterns of responding were not altered drastically. Thus, the interactions

between the behavior and shocks remained approximately the same before and after the change in lever position. Consider, however, the effects of an intervening treatment which results in an actual cessation of responding during a VI schedule of shock presentation. For example, a loose electrical connection in the stimulus lamp panel causes the lights to flicker. The monkey may orient towards the lamps and stop responding for a time. If a shock has been scheduled during the time that the monkey has stopped responding, the next response will produce the shock. The interaction between responding and shock presentation has been altered. Previously, shocks occurred during steady, moderate rates of responding. After the stimulus lamp malfunction, a response produced a shock following a pause. This new interaction is similar to an FR 1 schedule of shock presentation, and may result in further pausing and the eventual suppression of behavior (cf., Kelleher and Morse, 1968; McKearney, 1969).

The term metastability has been used by Staddon (1965) and Morse and Kelleher (1966, 1970) to describe "two different stable patterns of responding maintained under the same schedule parameters, one before and one after an intervening treatment" (Morse and Kelleher, 1970, p. 161). Metastability is a phenomenon associated with any behavior maintained by its consequences in the environment. However, it is most clearly seen in situations in which the maintenance of behavior also depends critically upon prior history and ongoing response patterns - such as behavior maintained under schedules of shock presentation.

These considerations of the conditions maintaining behavior under

schedules of shock presentation, and the modification of these conditions by disrupting stimuli, suggest that the failure to maintain VI behavior reported by Eubanks *et al*. (1973) may have been a result of the behavioral disruption accompanying the abrupt removal of TOs. Additionally, since VI behavior was maintained in the present study using constant-probability distributions of intervals and with no TOs following shocks, it appears that the presence of TOs following shocks is not a necessary condition for the maintenance of responding under VI schedules of shock presentation.

EXPERIMENT II. DEVELOPMENT AND CHRONIC MAINTENANCE OF RESPONDING UNDER CONCURRENT VARIABLE-INTERVAL, VARIABLE-INTERVAL SCHEDULES OF ELECTRIC-SHOCK PRESENTATION

In progressing towards the formulation of laws, science typically proceeds from the observation and manipulation of simple and isolated phenomena to increasingly complex experimentation. In the field of the Experimental Analysis of Behavior, for example, the initial focus of study is usually the thorough scientific understanding of variables controlling the emission of isolated operant responses. However, as more variables are identified, and experimental control becomes more precise, further experimentation is directed towards more complex occurrences of the response. The initial observations of the response in isolation are dictated by experimental exigencies: it is easier and more economical to identify major controlling variables when the response occurs in isolation from other responses. Temporarily, the response is studied much as if it were a discrete event. However, the heuristic value of this approach dwindles as the initial goals of identification of major variables are realized. There comes a point when the response must again be studied in the setting from which it was abstracted, that is, as one vicissitude in the continuous process of the behavior of an organism.

In the expanded study of the interaction of the response with other concurrently available responses, experimental attention focuses upon identification of controlling variables arising from the complex

situation itself. In many instances, studies of complex occurrences of the response result in the discovery of major independent variables which are not readily apparent in unelaborated situations (cf. Findley, 1962).

Previous studies (including Experiment I of this paper) showed that occasional presentations of response-dependent electric shocks maintained schedule-appropriate patterns of lever pressing. Experiment II was designed essentially to ask four questions concerning the development and maintenance of this behavior in a more complex situation. First, would monkeys press each of two levers when the only consequences of lever pressing were the occasional presentations of electric shocks. Second, if the monkeys did initiate responding on each lever, would they continue to respond, or would the responding be suppressed. Third, if the monkeys continued to respond, what types of patterns and what rates of responding would develop and be maintained. Fourth, could the interactions between the two operants be predicted on the basis of previous studies of concurrent operants maintained under schedules of food or water presentation.

Method

Subjects

Monkeys SM-38 and SM-432 were used.

Apparatus

The basic apparatus described in Experiment I was used. Plexiglas plates, designed to restrict lateral and vertical movements of the monkeys, were constructed. Their use is described in the following section delineating experimental procedures.

Procedure

Following the manipulations described in Experiment I, the two monkeys were responding under a VI 3 schedule of electric-shock presentation. The response lever was randomly alternated between the left and right positions from session to session. After 60 sessions, characteristic VI patterns of responding were being maintained at rates between 20 and 40 responses per min.

Development of concurrent responding with SM-38

With SM-38, two levers were inserted into the chamber at the same time following the 60 sessions under VI 3. The levers occupied the left and right positions in which they had previously been alternated. Concurrent 3-min variable-interval schedules of electric-shock presentation were programmed as consequences of responding on each lever. That is, responses on the left lever resulted in the presentation of shocks once every three minutes, on the average. Simultaneously, responses on the right lever also resulted in shock presentation according to an equal and independent VI 3 schedule. Following established procedures, a bi-directional changeover delay (COD) was programmed. This protective contingency ensured that changeover responses (e.g.,

a response on the left lever following a response on the right lever) were never followed immediately by shocks. This procedure specified that a changeover or switching response initiated a 0.50-sec interval during which scheduled shocks could not be delivered. The first response on the same lever to which the monkey had switched produced the scheduled shock, providing that the interval had elapsed. Responses on the alternate lever initiated another 0.50-sec interval.

Within three sessions after the introduction of concurrent schedules, it was apparent that the monkey's topography of responding was not conducive toward the development of concurrent responding. The monkey oriented toward a corner of the chamber, bending down and resting his head on the waistplate. This same orientation had occurred previously during avoidance and single-lever VI 3. In this position, the monkey could reach only one lever at a time, responded exclusively on that one lever (sometimes the left and sometimes the right), and did not look at the other lever. In an attempt to develop a topography in which the monkey oriented towards both levers at the same time, and which facilitated more frequent changeovers from one lever to the other, the chamber was modified in the following way. Two large Plexiglas plates were mounted on each side of the monkey to restrict lateral movements. Another Plexiglas plate was mounted between the two side plates to prevent the monkey from lowering his head below the levers. This plate extended up from the middle of the waistplate in front of the monkey, and then extended horizontally until it reached the front wall, just below the two levers.

The introduction of the restraint plates severely disrupted the monkey's behavior, such that few responses occurred on either lever.

In order to facilitate the development of responding with the restraints in position, the concurrent VI schedule was discontinued, one lever was removed from the chamber, and the shock-avoidance schedule was reintroduced. During 24 sessions of avoidance, with the lever position alternating from session to session, steady response rates of about 10 per min were obtained. Introduction of the VI 3 schedule of shock presentation resulted in significant response rate increases. After 20 sessions of VI 3, the monkey was responding with rates and patterns similar to those observed in Experiment I, but with the new restraints in place.

Two levers were again introduced into the chamber at the same time, and concurrent VI 3, VI 3 schedules of shock presentation were programmed. The 0.50-sec COD was in effect. The parameters of the concurrent schedule was subsequently changed to conc VI 3 (left), VI 1.5 (right) and then to conc VI 1.5 (left), VI 1.5 (right). The order of experimental conditions and the number of sessions of exposure to each procedure are presented in Table 1.

Development of concurrent responding with Monkey SM-432

A different procedure was used for developing concurrent responding with Monkey SM-432. The two Plexiglas side restraints were first introduced while the VI 3 schedule was still programmed. The presence of the restraints had little effect upon rates or patterns of responding when the lever was in the left position. However, responding on the right lever was disrupted, and response rates decreased to less than 5 per min after several sessions. In order to facilitate the redevelopment of responding when the lever was in the right position,

Table 1

The Order of Experimental Conditions and the Number of Sessions at Each Condition for Monkey SM-38, during the Development and Maintenance of Responding under Concurrent VI, VI Schedules of Electric-Shock Presentation.

Condition	Number of Sessions
Conc VI 3, VI 3 (restraints introduced)	3
Avoidance (lever position alternating)	24
VI 3: shock (lever position alternating)	20
Conc VI 3, VI 3	25
Conc VI 3 (left), VI 1.5 (right)	15
Conc VI 1.5, VI 1.5	30

the shock-avoidance schedule was programmed for sessions when the lever was in that position. The VI 3 schedule of shock presentation continued in effect when the lever was on the left side. After 9 sessions of avoidance, the VI 3 schedule was again programmed for right-lever responding. Characteristic steady rates of responding were maintained regardless of lever position, but the rates were much higher when the lever was on the left side than when it was on the right side. In an attempt to facilitate the development of equivalent rates of responding regardless of lever position, and with the restraints in place, concurrent avoidance schedules were programmed. Two levers were inserted into the chamber at the same time, and concurrent and independent 5-sec shock - shock intervals were programmed, as were concurrent and independent 20-sec response - shock intervals. A bi-directional changeover delay was programmed, such that each changeover response initiated a 0.50-sec interval during which responses were not effective in avoiding shocks.

Acquisition of concurrent avoidance responding was rapid. Within the first session, the monkey was responding on both levers, and within 5 sessions, shocks were being delivered at a rate of less than 10 per hour. Occasionally, shocks were delivered following a change-over response before the COD had elapsed. Response rates stabilized after about 10 sessions, although left-lever rates were higher than right-lever rates. Generally, concurrent avoidance responding was similar to that reported by Sidman (1962) and Verhave (1961).

Following 27 sessions of concurrent avoidance, concurrent VI schedules of shock presentation were introduced for the first time with

this monkey. Initially, the schedule was conc VI 3, VI 3; however, the parameters were changed to conc VI 3 (left) VI 1.5 (right) after 40 sessions. The order of experimental procedures and the number of sessions of exposure to each procedure is presented in Table 2.

With both monkeys, experimental sessions were conducted 6 days per week, lasted for 60 min, and were preceded and terminated by 4-min TO periods.

Results

Topography and Patterns of Concurrent Responding

With the Plexiglas restraint plates in position, the monkeys assumed an upright posture, facing the front wall, and resting the left hand on the left lever, and the right hand on the right lever. Left- and right-lever responses occurred with the left and right hands, respectively. Upon the introduction of the concurrent schedules, both monkeys responded at higher rates on the left lever than on the right lever. (It should be noted that at the end of Experiment I, responding was occurring at higher rates when the lever was on the right side.) After about 7 sessions, Monkey SM-38 responded at higher rates on the right lever than on the left lever.

The pattern of responding was one of alternation between levers, rather than one of simultaneous emission of the two responses. The manner of alternation controlled the rate disparity between the two responses. Bursts of responding on one lever (the left for SM-432, and first the left, and subsequently the right for SM-38) were followed by one or two responses on the other lever. This pattern of responding interacted with the COD such that shocks programmed for responding on the "lower-rate lever" were held in abeyance until the

Table 2

The Order of Experimental Conditions and the Number of Sessions at Each Condition for Monkey SM-432, during the Development and Maintenance of Responding under Concurrent VI, VI schedules of Electric-Shock Presentation.

Condition	Number of Sessions
VI 3: shock (barriers introduced) (lever position alternating)	16
VI 3 (left); Avoidance (right)	19
Conc AV, AV	27
Conc VI 3, VI 3	40
Conc VI 3 (left), VI 1.5 (right)	30

duration of a response burst exceeded the COD. Because of this interaction, some shocks programmed for the lower-rate lever were not actually produced until several minutes after they had been programmed. Conversely, responding on the other lever resulted in the presentation of shocks soon after they were programmed. The presentation of shocks resulted in rapid changeover responses between levers, but not in perseveration of responding on one or the other lever. Occasionally, shocks programmed for responding on one lever were produced during these rapid bursts of changeover responses following shocks produced for responding on the other lever.

Figures 4 and 5 show representative cumulative records of concurrent responding for Monkeys SM-38 and SM-432, respectively. Despite the differences in overall rates of responding on the two levers, steady rates of responding characteristic of VI schedules were maintained throughout the sessions on each lever.

Effects of Manipulating Parameter Values

Tables 3 and 4 summarize the effects on response and shock rates of changing the parameter value of one of the concurrent schedules. No significant changes in response rates accompanied any of the manipulations with either monkey. Increases in the scheduled density of shock presentations had differential effects upon shock rates, depending upon which lever the increase was scheduled for. For example, increasing the scheduled frequency of shocks for right-lever responding with SM-38 [from conc VI 3, VI 3 to conc VI 3 (left), VI 1.5 (right)] resulted in obtained shock rates approximating

Figure 4. Cumulative records representative of Monkey SM-38's performance during concurrent VI, VI schedules of electric-shock presentation.

SM-38

CONCURRENT VI 1.5, VI 1.5

SESSION 220

Figure 5. Cumulative records representative of Monkey SM-432's performance during concurrent VI, VI schedules of electric-shock presentation.


SM 432
LEFT
CONC. VI 3, VI 3
SESSION 150
RIGHT

Table 3

Successive Five-session Means of Response and Shock Rates on the Left and Right Levers for Monkey SM-38.

	Responses per Min		Shocks per Hour	
Schedule	Left	Right	Left	Right
Conc VI 3 VI 3	24.5	7.4	20.0	10.0
	16.1	18.6	20.0	19.0
	13.9	16.2	18.0	20.0
	8.5	20.8	14.3	20.2
	10.4	22.1	14.0	20.0
Conc VI 3 (L) VI 1.5 (R)	10.2	23.0	15.0	36.0
	13.0	21.1	14.5	37.0
	12.5	19.3	17.5	37.2
Conc VI 1.5 VI 1.5	11.9	20.1	21.0	36.0
	11.6	18.4	17.5	37.0
	9.0	18.3	16.0	33.0
	8.4	18.5	17.8	38.0
	9.5	17.5	16.0	37.0
	9.5	17.8	16.0	35.0

Table 4

Successive Five-session Means of Response and Shock Rates on the Left and Right Levers for Monkey SM-432.

	Responses per Min		Shocks per Hour	
Schedule	Left	Right	Left	Right
Conc VI 3 VI 3	31.1	9.5	20.0	16.0
	34.0	9.5	19.5	12.0
	28.5	9.2	21.0	13.8
	24.2	7.0	20.0	14.5
	26.4	6.9	19.0	12.0
	23.2	6.8	18.5	14.0
	25.0	5.2	20.5	10.2
	27.9	3.7	20.5	8.0
Conc VI 3 (L) VI 1.5 (R)	31.3	6.0	20.0	12.5
	28.4	6.3	18.5	9.0
	25.5	6.8	20.0	13.5
	24.8	5.0	20.0	8.5
	25.8	4.1	20.0	6.5
	25.3	3.5	20.0	5.5

the scheduled frequency, that is about 40 shocks per hour. However, increasing the scheduled frequency of shocks programmed for left lever responding had little effect upon obtained shock rates for that response. Presumably, the patterns of response alternation in interaction with the COD maintained the obtained shock rates at invariant levels. Thus, shock rates and response rates on the left lever were unresponsive to parameter changes of the schedule for that lever.

A similar invariance of patterns of responding influencing obtained shock rates was evident with SM-432. The initial increases in shock rates for right lever responding when the higher density, VI 1.5 schedule was first introduced were transient, and represented only about 30 percent of shocks actually scheduled.

Discussion

In Experiment II, responding was developed and chronically maintained on two levers under concurrent and simultaneous schedules of electric-shock presentation. By responding on each of the two available levers, the monkeys effected an increase in the frequency with which shocks were presented. The patterns of responding on each lever resembled the steady, moderate rates of responding characteristically maintained by VI schedules. These results complement previous reports of the maintenance of characteristic response patterns by FI (Kelleher and Morse, 1968; McKearney, 1968), FR (McKearney, 1970), and VI (McKearney, 1972; Experiment I of the present study) schedules in a single-response situation.

The patterns of responding on the two levers were also similar

to patterns occurring during concurrent variable-interval schedules of food or water presentation. The lack of any systematic effect on rates of responding of changing the parameter value of one of the concurrent schedules, could also be predicted from the results of previous studies of concurrent schedule interactions. As Baum (1974) has pointed out, and Iglauer and Woods (1974) have confirmed, changes in the scheduled frequency of reinforcement affect behavior only when the behavior comes into contact with the change. (Or, put another way, experimental changes may affect the behavior of the experimenter but not of the subject.) In the present experiment, the stereotyped patterns of alternation between the two responses negated the scheduled increase in shock density, and the obtained frequency of shocks remained the same from condition to condition on the low-rate lever. It should be noted, however, that an increase in the obtained shock frequency with SM-38, when the schedule was changed from conc VI 3, VI 3 to conc VI 3 (left), VI 1.5 (right), resulted in a relative increase in rates of the response with the lower shock density. If this effect occurs in succeeding studies of concurrent schedules of shock presentation, it would imply a preference for that response which produces fewer shocks. No definitive statement of that nature could be made on the basis of the present results, since in every condition, the response producing the higher shock frequency was also emitted at a higher rate.

In predicting the interaction of responses under concurrent schedules with qualitatively similar reinforcers, the relative frequency of one response often approximates the relative frequency with which it is

reinforced (Herrnstein, 1961). The proportion of responses on the left lever as a function of the proportion of shocks produced for those responses during the last five sessions of each condition were calculated, and are presented in Table 5. Since only five determinations were possible for the two monkeys, the data are only suggestive, and are presented merely to facilitate comparisons with other studies. With SM-38, the values indicate "preference" (greater response output) for the right lever response over and above that which is predicted by the matching relationship. With SM-432, preference for the left lever response shows a similar "overmatching." Baum (1974) suggests that the proportional expression of the matching relationship, while useful, does not make allowances for the presence of a systematic and invariant response bias - such as position preference, hand prepotency, etc. Since the topography of responding in the present study may be considered such a bias, the relationship between responses and shocks for the two levers were also calculated as the ratio of the two responses and the ratio of the shocks obtained for the two responses. Baum argues that logarithmic plots of these ratios (for several determinations) graphically portray bias as a systematic deviation from the line of perfect matching. The obtained left-to-right ratios are also presented in Table 3. Obviously, no systematic deviation occurred between monkeys, nor with each individual monkey for the limited number of determinations.

Although the matching relationship often correctly predicts response preferences, it by no means accounts for response interactions in all studies of concurrent responding (e.g., Holland and Davison, 1971; Trevett, Davison, and Williams, 1972). Additionally, in the

Table 5

Relative Measures of Responses and Shocks

I. Proportion of responses on the left lever, and proportion of shocks obtained for those responses during the last five sessions of each condition

	SM-38		SM-432	
Schedule	Responses	Shocks	Responses	Shocks
Conc VI 3 VI 3	.27	.29	.87	.73
Conc VI 3 (L) VI 1.5 (R)	.40	.33	.88	.84
Conc VI 1.5 VI 1.5	.37	.30		

II. Ratio of left to right responses, and ratio of left to right shocks

Conc VI 3 VI 3	.38	.39	6.91	2.81
Conc VI 3 (L) VI 1.5 (R)	.67	.48	7.11	3.90
Conc VI 1.5 VI 1.5	.60	.45		

present experiment, the ongoing topographical preference for one of the levers prevented the observations of the effects upon rates of responding of changes in shock rates for each of the operants, in a manner comparable to many other studies of concurrent operants.

OVERVIEW

The results of Experiment II fully answered three of the four questions asked at its outset. The monkeys did press each of the levers, the responding was chronically maintained, and the patterns of responding were comparable to those seen in Experiment I in the single-response situation. Thus, the generality of the phenomenon of behavior maintained by response-contingent presentations of shock has been extended to a much more complex situation.

Unfortunately, two interrelated aspects of the experiment may forestall comparisons with other studies of concurrent behaviors: 1) the topography of the responses and 2) the lack of effects upon response and shock rates of manipulations of the schedule parameter values. The fact that the two responses could be emitted simultaneously, and the degree to which this aspect of topography attenuated the effects of experimental manipulations, may raise questions concerning the propriety of including this study within the archival literature of concurrent operants. The conditions responsible for this potentiality are rooted within the methodological history of the study of concurrent operant behaviors, and are best explained within that context.

Classification of Concurrent Operants

With respect to the classification of concurrent operants, a distinction is made between compatible and incompatible responses with regard to topography. For example, in the present situation, since the

levers were a short distance apart, the monkeys could respond on the two levers simultaneously or in rapid succession. The two responses are topographically compatible, although the locus of topography is different. If the environment were changed, such that the levers were moved 10 feet apart, simultaneous responding on the two levers would be impossible. The responses would be called incompatible. Insofar as compatibility or incompatibility may affect the frequency with which an organism engages in two or more behaviors, these aspects of topography are of considerable importance in specifying the determinants of the behaviors. Historically, topographical compatibility or incompatibility were not proposed as defining characteristics of concurrent operants, but formed a basis for the description of the interactions between responses, and were applied to both reflex and operant responses (Skinner, 1938). However, contemporary redefinitions of concurrent operants have included these aspects of topography as properties integral to formal laboratory investigations. For example, Ferster and Skinner (1957) characterized concurrent operants as

> two or more responses, of different topography at least with respect to locus, capable of being executed with little mutual interference at the same time or in rapid succession, under the control of separate programming devices (e.g., responses to two keys present at the same time under separate schedules). (p. 724)

Ferster and Skinner provided no rationale for the demand that concurrent operants be amenable to easy mutual execution. Casual observations of behavior reveal many instances of operants which are concurrent with respect to locus of availability, but are not susceptible to mutual execution once one of the operants is emitted (chosem). Indeed, the choice of one of a number of concurrently available operants may render impossible the opportunity for engaging in other behaviors.

For example, if travel comprises one component of a behavior which is chosen, the spatial and temporal separation from the environment in which the other behaviors are available negates the possibility for simultaneous emission or rapid alternation.

Independence of Concurrent Operants

Although Ferster and Skinner (1957) appear to have favored studies of concurrent operants employing responses capable of simultaneous or nearly simultaneous emission, later investigators have focused experimental attention almost exclusively upon incompatible concurrent operants. For example,

> It would appear that a necessary condition for the maximal independence of two or more operants is that they be topographically compatible so that they can occur at the same time as well as in succession....In practice, however, topographical compatibility often leads to an incompatibility, with respect to separation of the control of concurrents by their respective schedules of reinforcement. (Catania, 1966, p. 214)

and

> If it is correct that the simultaneity of concurrent operants is incompatible with the independence of concurrent operants, concurrent procedures must provide that responses occur only in succession. (Catania, 1966, p. 219-220)

Catania's insistence upon some degree of incompatibility among concurrent operants reflects special problems involved in the analysis of variables controlling one or more of the responses. Two behaviors which occur simultaneously or in rapid succession may both be maintained in an adventitious relationship by the consequences resulting from only one of the behaviors. Concurrent superstitions of this type pose a problem for the experimental analyst interested in studying the interactions between concurrent behaviors and their respective consequences.

Just as the initial tactics of research dictated the importance of

studying a single response in isolation, so also have tactics led to the study of concurrent operants in situations designed to ensure incompatibility, and presumably, independence. By providing experimental situations in which each response may be controlled separately, each by its own consequences, the identification of major variables controlling concurrent interactions has proceeded steadily, if not rapidly.

A danger inherent in adopting the tactic of primarily studying incompatible and/or independent concurrent operants is the exclusion from study of compatible and/or dependent concurrent operants. The degree to which concurrent operants, compatible or incompatible, may occur under independent stimulus and schedule control is itself a variable of importance. Similarly, the extent of compatibility or incompatibility is a variable, not a defining property of concurrent operants. Viewed in these terms, compatibility and incompatibility should be recognized as end points along a topographical continuum, the parameters of which may be defined either spatially or temporally.

EXPERIMENT III. SUPPRESSION OF RESPONDING UNDER CONCURRENT VARIABLE-INTERVAL, EXTINCTION SCHEDULES OF ELECTRIC-SHOCK PRESENTATION

The preceding discussion exposed some of the analytic drawbacks and conceptual predispositions which might hinder the comparison of the results of Experiment II with other studies of concurrent operants. Indeed, one of these problems bears upon the rationale for actually conducting the experiment. The primary objective of the experiment was discovering whether or not a response whose only consequence was the presentation of electric shocks would be maintained when the opportunity to engage in other operant responses was also available. Since both responses were maintained, regardless of the locus of control, explicit or adventitious, the experimental question was answered in the affirmative. However, as Catania (1966) pointed out, if one response is adventitiously maintained by the consequences of a second response, the first response must be analyzed as a member of a chain, rather than as one of two alternatives in a choice situation.

Experiment III was designed to assess whether or not the two responses occurred in a chaining relationship, or whether they were actually maintained by the consequences programmed for each. The most widely accepted procedure for demonstrating independence of this type calls for the establishment of schedule control for each of the responses. Changes in the consequences of one response should

then be reflected in changes in the rates or patterns of responding, or in the relative distribution of responses. Those types of changes did not occur in Experiment II when the schedule of shock presentation for the low-rate lever was changed from VI 3 to VI 1.5. It was contended that the interactions among topography of responding, engagement of the COD, and stereotyped ongoing patterns of responding allowed no opportunity for the behavior to come into contact with the new contingencies.

Since increasing the scheduled shock density was a futile manipulation without discontinuing the COD, that option was discarded. Similarly, since the use of a COD is one of the main guarantors of response independence, discontinuing that contingency might have been a step backwards. One manipulation which was certain to come into contact with the behavior was changing one of the VI schedules to extinction. This procedure had several advantages. First, it would result in a change in obtained shock rates. Second, the nature of the control of responding would be clarified. If response rates did not change, presumably the response was being maintained adventitiously. If the rate did change, responding was presumably under the control of the explicitly programmed consequences. Third, a number of studies have examined the effects of extinction upon shock-maintained responding (e.g., Kelleher and Morse, 1968). When responses no longer produced shocks, response rates decreased to very low levels. The responding returned to baseline levels when shocks were again presented. Fourth, the effects of extinction on one of two responses maintained under concurrent variable-interval schedules of food presentation

(Brownstein and Pliskoff, 1968; Catania, 1963; Herrnstein, 1961; Stubbs and Pliskoff, 1969) and point production (Catania and Cutts, 1963) are well documented. In most of these experiments, one of the VI schedules was held constant, and the parameter value of the other schedule was manipulated. In all cases, when the second schedule was extinction, very few responses occurred on the manipulandum for which extinction was programmed. Rates of emitting the other response which still resulted in reinforcement either remained the same or increased.

In the study by Catania and Cutts, human subjects received points on a counter according to a 30-sec variable-interval schedule. Two buttons were located on the panel facing the subjects, but reinforcement was programmed for pushing only one of the buttons. The presence or absence of a 4.5-sec COD differentially affected rates and patterns of pushing the button on which extinction was programmed. When this protective contingency was in effect, very few pushes occurred on the extinction button, while high rates were maintained on the other button. When no COD was programmed, equivalent rates of responding on the two buttons often occurred. Generally, much higher rates of pushing the extinction button occurred when the COD was not programmed, indicating that the response was adventitiously maintained by the consequences programmed for the other button. In a similar experiment with pigeons, the presence or absence of the COD had similar effects upon the maintenance of the response under extinction.

Method

Subjects and Apparatus

Monkeys SM-38 and SM-432 were used with the same apparatus.

Procedure and Results

At the beginning of this experiment, the two monkeys were responding concurrent VI schedules of electric-shock presentation. With Monkey SM-38, the schedule was conc VI 1.5, VI 1.5; with Monkey SM-432, the schedule was conc VI 3 (left), VI 1.5 (right). A 0.50-sec COD was programmed.

After 30 sessions the schedule programmed for responding on the right lever was changed to extinction; that is, responding on the right lever no longer resulted in shock presentations. The results of this manipulation are shown in the first two panels of Figures 6 and 7.

With Monkey SM-38, responding on the left lever, on which shocks were still programmed, decreased from 15 responses per min to less than 1 response per min within 3 sessions. Responding on the right, "extinction," lever, decreased from 25 to 7 responses per min. The decreases in response rates were characterized by gradual decelerations rather than by abrupt transitions from high to low rates. Although left-lever responding was suppressed by the end of the 3rd session of this manipulation (session 33 on Figure 6), right-lever responding continued into the next session before being suppressed entirely.

With Monkey SM-432, no immediate effects of the schedule change were apparent. However, over a period of 50 sessions, while left-lever responding remained constant at about 20 responses per min, right-lever response rates increased from less than 3 per min to more than 11 per min. By session 87, right-lever rates had reached 16 responses per min, and were higher than left-lever rates for the first time under any

Figure 6. Response rates and shock rates for Monkey SM-38. The open symbols indicate responding on the right lever; the filled symbols indicate responding on the left lever. The parameter value of the schedule for the left lever is always given first in designating each condition.

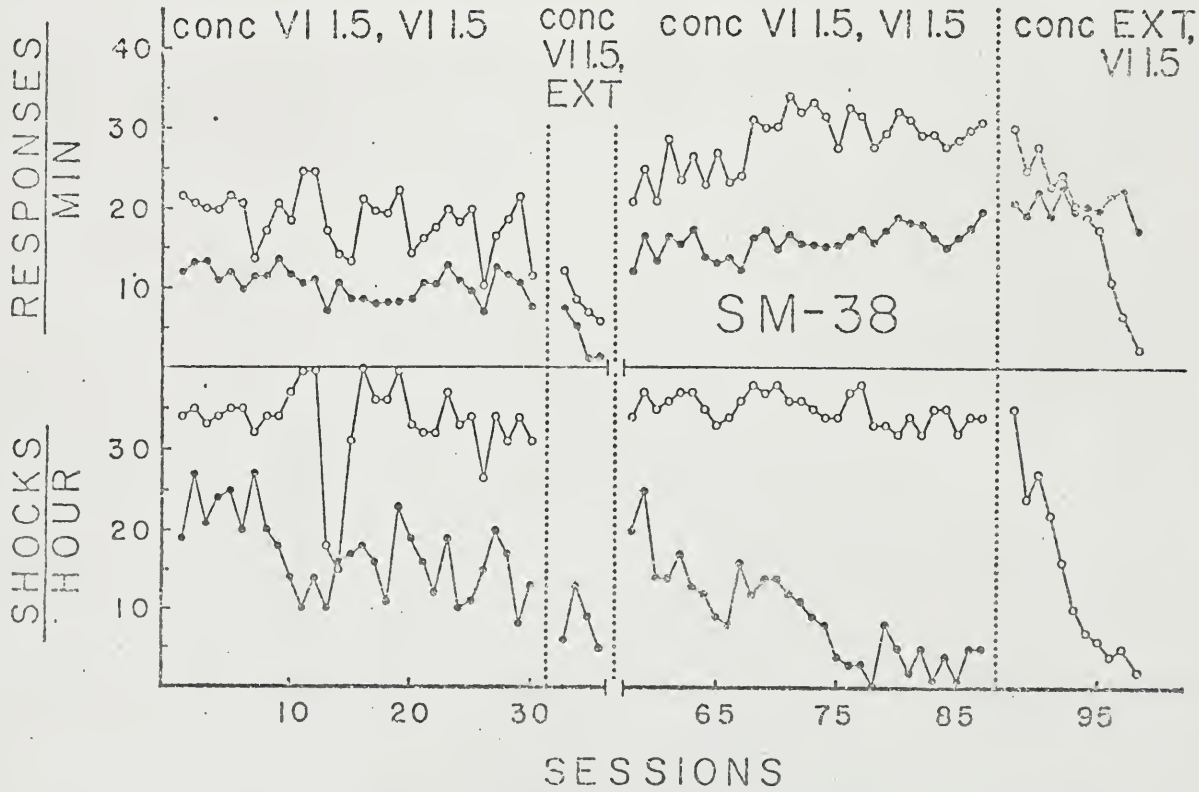
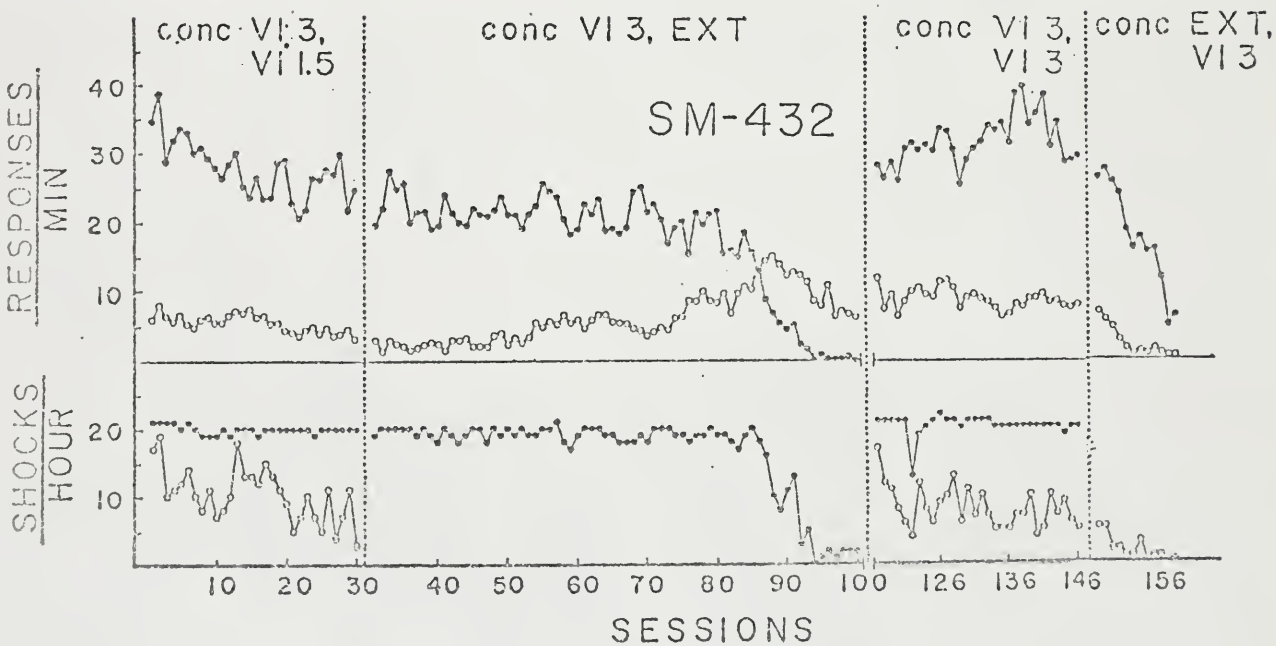

conc VI 1.5, VI 1.5
conc VI 1.5, EXT
conc VI 1.5, VI 1.5
conc EXT, VI 1.5
SM-38
RESPONSES / MIN
40
30
20
10
SHOCKS / HOUR
30
20
10
10
20
30
65
75
85
95
SESSIONS

Figure 7. Response rates and shock rates for Monkey SM-432. The open symbols indicate responding on the right lever; the filled symbols indicate responding on the left lever. The parameter value of the schedule for the left lever is always given first in designating each condition.


conc VI 3, VI 1.5
conc VI 3, EXT
conc VI 3, VI 3
conc EXT, VI 3
SM-432
RESPONSES / MIN
40
30
20
10
SHOCKS / HOUR
20
10
10 20 30 40 50 60 70 80 90 100 126 136 146 156
SESSIONS

condition of concurrent schedules with this monkey. From session 87 to session 100, left-lever rates decreased from 15 to less than 1 response per min. Typical VI patterns of responding occurred until session 98, when short bursts of responding alternated with long pauses. During the 13 sessions of suppression of left-lever behavior, responding on the right lever occurred at steady rates between 6 and 12 responses per min. All responding ceased during the 71st session of conc VI 3 (left), EXT (right) (session 101 on Figure 7).

Following the suppression of responding under the concurrent VI, EXT schedule, concurrent VI, VI schedules of shock presentation were reintroduced. Although occasional responses occurred on both levers, usually followed by shocks, the behavior of both monkeys was still suppressed after 10 sessions of concurrent VI, VI.

The sequence of procedures described in Experiment II were then employed to redevelop concurrent responding. With Monkey SM-38, 9 sessions of avoidance was followed by 10 sessions of VI 3; in both conditions, the position of the lever was alternated from session to session. On the 20th day of retraining, concurrent 1.5-min VI schedules were programmed.

With SM-432, 18 sessions under the concurrent avoidance schedule preceded introduction of conc VI 3, VI 3.

Reacquisition of the concurrent VI, VI performance was rapid. As is shown in Figures 6 and 7, the two monkeys responded at slightly higher rates on both levers than during the previous condition under concurrent VI, VI. After 30 sessions, extinction was programmed for responding on the left lever. With both monkeys, responding on the

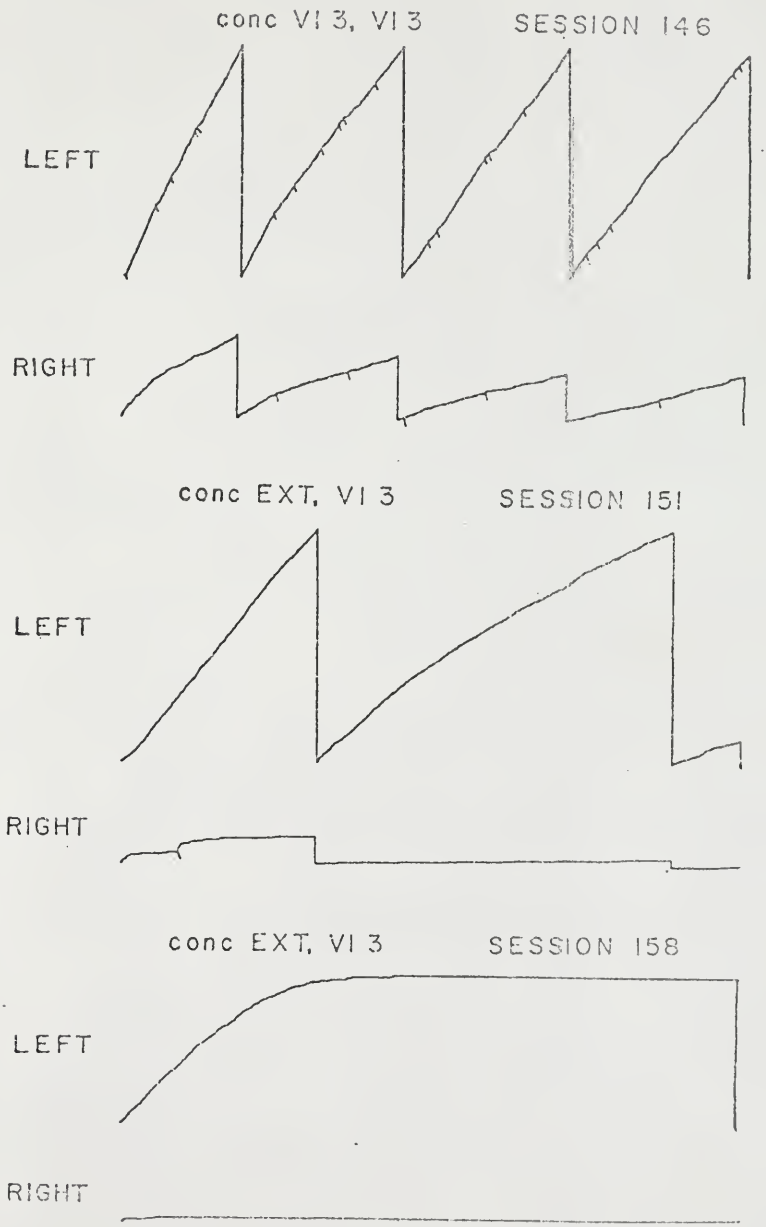
right, "shock," lever decreased to rates of less than 1 response per min within 10 sessions. Responding on the left, "extinction," lever remained at rates of about 20 per min, until responding was suppressed on the right lever. Thereafter, left-lever rates decreased to zero in a negatively accelerated pattern within the next two or three sessions. Cumulative records showing the transition from response maintenance to response suppression during this phase for SM-432 are presented in Figure 8.

Discussion

The results of Experiment III are similar neither to the effects of extinction of a response maintained by schedules of shock presentation in a single-response situation, nor to the effects of extinction of one of two concurrent responses maintained under schedules of food or point presentation. In some respects, the results are similar to the effects on a punished response of the availability of an unpunished alternative response (Azrin and Holz, 1966). In that experiment, pigeons' responses on one key resulted in both food and shock. Responding was not significantly suppressed at low and moderate intensities of electric shock. When the intensity was increased further, response rates decreased, but a surprising number of responses were still occurring even at high shock intensities. When a second key was uncovered, and responses directed against this key resulted in food presentation at equivalent frequencies to the first response, but without the presentation of shocks, the pigeons responded on the second key exclusively. Responding on the second key remained prepotent even at intensities of shock on the first key which had little effect

Figure 8 Representative cumulative records for Monkey S1-432 showing the transition from response maintenance to response suppression during the second exposure to the extinction condition. In each record, the schedule programmed for responding on the left lever is presented first. The sessions are numbered to correspond to Figure 7.

SM-432


conc VI 3, VI 3
SESSION 146
LEFT
RIGHT
conc EXT, VI 3
SESSION 151
LEFT
RIGHT
conc EXT, VI 3
SESSION 158
LEFT
RIGHT

upon responding in the absence of the alternative response. Since each response produced a characteristic consequence - food presentation - these results are not entirely applicable to the present experiment. The main point of interest is the difference in rates of responding on the punished key as a function of the presence of another response.

When considered within this context, the results of the present experiment suggest that the degree to which behavior will be maintained by schedules of shock presentation may be greatly affected by the availability of other responses. The results do not suggest that this effect will necessarily result in the suppression of behavior since the two operants were maintained when each produced shocks. Further research should examine conditions in which responses on one manipulandum result in shock presentation, and responses on a second manipulandum result in a qualitatively different stimulus - for example, food presentation.

Experiment III did indicate that the two responses were under the control of the consequences programmed for each. If one of the two responses had been maintained in an adventitious relationship by the consequences of the other response, then discontinuing shocks programmed for that response should have had little effect upon either response. The fact that similar effects on responding occurred during extinction of each response in two separate conditions and with both monkeys is evidence that the two operant responses were independent, and were under the control of their respective consequences.

The failure to recover the previous rates and patterns of respond- following the suppression of behavior under the concurrent VI, EXT schedule by reprogramming the concurrent VI, VI schedule was not surprising. The steady, ongoing response rates were no longer present. Reintroduction of the concurrent VI, VI schedule resulted in a low ratio of responses to shocks. After several sessions of a few responses alternating with long pauses, no further responding occurred. The behavior probably could have been restrengthened if the the concurrent VI, VI schedules were reintroduced while responding was occurring at steady, although low, rates.

Kelleher and Morse (1968) and McKearney (1969) have shown previously that the same intensity of shocks either maintains or suppresses behavior depending upon the schedule under which it is presented. Similarly, depending upon the previous history of responding, the same paramters of FI schedules of shock presentation will either suppress or enhance responding (Azrin and Holz, 1966; Morse and Kelleher, 1970). In the present experiment, behavior was both maintained and suppressed by the same schedules of shock presentation, after the same history, depending upon the consequences programmed for a second, concurrent response. These results provide further emphasis for Morse and Kelleher's (1970, Pp. 172-175) conclusions that the effects of stimuli upon behavior change when the conditions under which the behavior occurs are changed.

REFERENCES

Azrin, N. H. and Holz, W. C. Punishment. In W. K. Honig (Ed.), Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 380-447.

Baum, W. M. On two types of deviation from the matching law: bias and undermatching. Journal of the Experimental Analysis of Behavior, 1974, 22, 231-242.

Brownstein, A. J. and Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 683-688.

Byrd, L. D. Responding in the cat maintained under response-independent and response-produced electric shock. Journal of the Experimental Analysis of Behavior, 1969, 12, 1-10.

Byrd, L. D. Responding in the squirrel monkey under second-order schedules of shock delivery. Journal of the Experimental Analysis of Behavior, 1972, 18, 155-167.

Catania, A. C. Concurrent performances: reinforcement interaction and response independence. Journal of the Experimental Analysis of Behavior, 1963, 6, 253-263.

Catania, A. C. Concurrent operants. In W. K. Honig (Ed.), Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966. Pp. 213-270.

Catania, A. C. and Cutts, D. Experimental control of superstitious responding in humans. Journal of the Experimental Analysis of Behavior, 1963, 6, 203-208.

Eubanks, J. L., Killeen, P., and Hamilton, B. Post-shock pause reinforces responding in schedules of shock presentation. Presented at the meeting of the American Psychological Association, Montreal, September, 1973.

Ferster, C. B. and Skinner, B. F. Schedules of reinforcement. New York: Appleton-Century-Crofts, 1957.

Findley, J. D. An experimental outline for building and exploring multi-operant repertoires. Journal of the Experimental Analysis of Behavior, 1962, 5, 113-166.

Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. Journal of the Experimental Analysis of Behavior, 1962, 5, 529-530.

Hake, D. F. and Azrin, N. H. An apparatus for delivering pain shock to monkeys. Journal of the Experimental Analysis of Behavior, 1963, 6, 297-298.

Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.

Hollard, V. and Davison, M. C. Preference for qualitatively different reinforcers. Journal of the Experimental Analysis of Behavior, 1971, 16, 375-380.

Iglauer, C. and Woods, J. H. Concurrent performances: reinforcement by different doses of intravenous cocaine in rhesus monkeys. Journal of the Experimental Analysis of Behavior, 1974, 22, 179-196.

Kelleher, R. T. and Morse, W. H. Schedules using noxious stimuli. III. Responding maintained with response-produced electric shock. Journal of the Experimental Analysis of Behavior, 1968, 11, 810-838.

Malagodi, E. F., DeWeese, J., Webbe, F. M., and Palermo, G. Responding maintained by schedules of electric-shock presentation. Presented at the meeting of the Psychonomic Society, St. Louis, November, 1973.

McKearney, J. W. Maintenance of responding under a fixed-interval schedule of electric-shock presentation. Science, 1968, 160, 1249-1251.

McKearney, J. W. Fixed-interval schedules of electric-shock presentation: extinction and recovery of performance under different shock intensities and fixed-interval durations. Journal of the Experimental Analysis of Behavior, 1969, 12, 301-313.

McKearney, J. W. Responding under fixed-ratio and multiple fixed-interval fixed-ratio schedules of electric shock presentation. Journal of the Experimental Analysis of Behavior, 1970, 14, 1-6.

McKearney, J. W. Maintenance and suppression of responding under schedules of electric shock presentation. Journal of the Experimental Analysis of Behavior, 1972, 17, 425-432.

Morse, W. H. and Kelleher, R. T. Schedules using noxious stimuli. I. Multiple fixed-ratio and fixed-interval termination of schedule complexes. Journal of the Experimental Analysis of Behavior, 1966, 9, 267-290.

Morse, W. H. and Kelleher, R. T. Schedules as fundamental determinants of behavior. In W. N. Schoenfeld (Ed.), The theory of reinforcement schedules. New York: Appleton-Century-Crofts, 1970. Pp. 139-185.

Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. Science, 1953, 118, 157-158.

Sidman, M. Reduction of shock frequency as a reinforcement for avoidance behavior. Journal of the Experimental Analysis of Behavior, 1962, 5, 247-257.

Skinner, B. F. The behavior of organisms: an experimental analysis. New York: Appleton-Century-Crofts, 1938.

Staddon, J. E. R. Some properties of spaced responding in pigeons. Journal of the Experimental Analysis of Behavior, 1965, 8, 19-27.

Stretch, R., Orloff, E. R., and Dalrymple, S. D. Maintenance of responding by a fixed-interval schedule of electric-shock presentation in squirrel monkeys. Science, 1968, 162, 583-585.

Stretch, R., Orloff, E. R., and Gerber, G. J. Multiple interruptions of responding maintained by a fixed-interval schedule of electric-shock presentation in squirrel monkeys. Canadian Journal of Psychology, 1970, 24, 117-126.

Stubbs, D. A. and Pliskoff, S. S. Concurrent responding with fixed relative rate of reinforcement. Journal of the Experimental Analysis of Behavior, 1969, 12, 887-895.

Trevett, A. J., Davison, M. C., and Williams, R. J. Performance in concurrent interval schedules. Journal of the Experimental Analysis of Behavior, 1972, 17, 369-374.

Verhave, T. Some observations concerning prepotency and probability of postponing shock with a two-lever avoidance procedure. Journal of the Experimental Analysis of Behavior, 1961, 4, 187-192.

BIOGRAPHICAL SKETCH

The author of this dissertation, Frank M. Webbe, was born in Vero Beach, Florida on the 13th of October, 1947, to Richard and Peggy Webbe. He attended high school in Miami, and received the Bachelor of Arts degree from the University of Florida in 1969. He is married to the former Ellen Marie Kane, and he and Mrs. Webbe are the parents of two children, Elizabeth St. Clare and Tristan Kane.

Since receiving the Bachelor of Arts degree, he has matriculated through the Graduate School of the University of Florida, receiving the Master of Science degree in 1971. He has been active both in research and teaching during his tenure as a graduate student, and plans to continue an academic career.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. F. Malagodi

E. F. Malagodi, Chairman
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Marc N. Branch

Marc N. Branch
Assistant Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Henry S. Pennypacker
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Carol VanHartesveldt

Carol J. VanHartesveldt
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William Wolking
Professor of Special Education

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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Dean, Graduate School