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Reinforcement Increases the Strength of an Elicited Response

Michael D. Peters
Western Michigan University

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REINFORCEMENT INCREASES THE STRENGTH OF AN ELICITED RESPONSE

by

Michael D. Peters

A Dissertation
submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Doctor of Philosophy
Department of Psychology

Western Michigan University
Kalamazoo, Michigan
December 1985
REINFORCEMENT INCREASES THE STRENGTH OF AN ELICITED RESPONSE

Michael D. Peters, Ph.D.
Western Michigan University, 1985

A response initially produced by noncontingent fixed-time delivery of brief electric shock was strengthened by reinforcement. Following the fixed-time shock baseline condition, response contingent shock absence (avoidance) was programmed for the lower probability of two response options for one group of squirrel monkeys. For the other group the interposed history was variable-interval food reinforcement. When responding was reliably maintained reinforcement was discontinued and a return made to fixed-time shock conditions as programmed prior to reinforcement. Upon a return to original conditions, rates were substantially elevated over baseline with the elevation sustained for many sessions. The avoidance group showed the most dramatic effects with rate increases on the manipulandum for which reinforcement had been programmed as well as a large rate increase on the manipulandum for which no reinforcement was provided. The present findings confirm previous work in showing substantial and continuing rate enhancement effects of reinforcement in the absence of current contingencies.
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ACKNOWLEDGEMENTS

The help of my committee members Dr. M. K. Malott, Dr. D. O. Lyon, Dr. R. R. Hutchinson and Dr. L. Supnick in this project is appreciated. The research was conducted at the Foundation for Behavioral Research with the assistance of Dr. G. S. Emley and T. Proni. The assistance of M. Nixon in data collection and the general maintenance of experimental subjects is greatly appreciated. The author was supported in part by a doctoral associateship from Western Michigan University.

Michael D. Peters
# Table of Contents

ACKNOWLEDGEMENTS ................................................................. ii

LIST OF TABLES ................................................................. iv

LIST OF FIGURES ............................................................... v

INTRODUCTION ................................................................. 1

EXPERIMENT 1 ................................................................. 6
  Method ................................................................. 6
  Subjects ............................................................. 6
  Apparatus ............................................................. 6
  Procedure ............................................................. 7
  Results ................................................................. 8
  Brief Discussion ..................................................... 21

EXPERIMENT 2 ................................................................. 23
  Method ................................................................. 23
  Subjects ............................................................. 23
  Apparatus ............................................................. 23
  Procedure ............................................................. 23
  Results ................................................................. 26
  Brief Discussion ..................................................... 33

GENERAL DISCUSSION ....................................................... 36

BIBLIOGRAPHY ................................................................. 41

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LIST OF TABLES

1. Experimental Conditions for Experiment 1 ............ 9
2. Experimental Conditions for Experiment 2 ............ 25
LIST OF FIGURES

1. Five Session Means of Session Totals for Subject MC-106 ... 11
2. Five Session Means of Session Totals for Subject MC-89 ... 13
3. Cumulative Records for One Subject (MC-106) Prior To, During and After Avoidance Conditioning ... 15
4. Cumulative Records from Sessions of Subject MC-89 ... 17
5. Five Session Means of Lever Presses for Subject MC-72 Across All Experimental Conditions ... 27
6. Five Session Means of Lever Presses for Subject MC-105 Across All Experimental Conditions ... 29
7. Sample Cumulative Lever Press Records for Subjects Under Fixed-Time Shock Conditions Prior to Variable-Interval Food Reinforcement and for Some Sessions After ... 31
INTRODUCTION

A number of researchers have found behavior persistently maintained by response produced electric shock. This surprising effect is in direct conflict with a large body of literature showing response contingent shock delivery to be punishment, a response weakening operation. Responding has been maintained by response contingent fixed-interval schedules of shock presentation with cats (Byrd, 1969), and squirrel monkeys (Morse & Kelleher, 1970; Morse, Mead & Kelleher, 1967; Stretch, Orloff & Dalrymple, 1968). A consistent feature of paradigms which result in persistent responding under response contingent shock has been the application of a more typical reinforcement history prior to exposure to response contingent shock. These reinforcement histories have included avoidance conditioning (Byrd, 1969; McKearney, 1968, 1969; Stretch, Orloff & Dalrymple, 1968), escape from shock (Morse & Kelleher, 1970) and schedules of response contingent food reinforcement (Morse & Kelleher, 1970).

Can shock be a reinforcer and have studies which used the contingent delivery of shock to maintain responding shown this? The noncontingent delivery of brief electric shock in itself generates substantial rates of behavior. With the availability of a chain or lever, fixed-time noncontingent shock causes considerable manual manipulative responding by squirrel monkeys (Hutchinson, Renfrew & Young, 1971). Responding under fixed-time noncontingent shock is characterized by the absence of, or low rates of responding post shock followed by
acceleration of responding later in the shock-shock interval. This response pattern is characterized of fixed-interval schedules of food reinforcement (Ferster & Skinner, 1957, pp. 133-335) and occurs in the absence of prior exposure to a response strengthening contingency (Hutchinson & Emley, 1972; Hutchinson, Renfrew & Young, 1971). These response-independent shock studies show that a contingency is not necessary for responding to be maintained by shock. It may be that in studies of response-produced shock responding is maintained by shock as an antecedent stimulus rather than maintained by shock as a reinforcer.

While it has been shown that behavior can be maintained by non-contingent shock, we also know that reflexes can be strengthened by consequences. Konorski and Miller (1937) cite the example of a leg-lift reflex under control of antecedent electric shock delivery. Food reinforcement for the leg-lift response resulted in response strength in the absence of shock delivery. Brogden, Lipman and Culler (1938) used a response contingent shock-offset procedure (escape) to elevate wheel running controlled by antecedent electric shock. A control group for which shock could not be escaped showed no comparable rate increase. These studies show that what is commonly called reflex behavior is modifiable by reinforcement. However, no information is provided about what the later effects of the history might be if conditions of antecedent stimulation were once again imposed.

There are also studies which have shown that responding under consequent control will later be emitted with strength under
noncontingent shock delivery. Following avoidance conditioning, responding remains at strength under conditions of noncontingent shock. Sidman, Herrnstein and Conrad (1957) programmed fixed-time noncontingent shock for rhesus monkeys after sessions of avoidance conditioning. It was shown that responding could be maintained at substantial rates under these conditions. Later, Waller and Waller (1963) with dogs and Kelleher, Riddle and Cook (1963) with squirrel monkeys found that responding which had previously been maintained by a shock avoidance contingency continued in strength in the presence of a pre-aversive stimulus which terminated in brief, response-independent electric shock. These studies (Kelleher, Riddle & Cook, 1963; Sidman, Herrnstein & Conrad, 1957; Waller & Waller, 1963) show a response previously maintained by consequent stimulus delivery (response-indepent shock). However, responding was not observed under conditions of noncontingent shock prior to avoidance conditioning. Thus, no comparison may be made between the response strength attributable to response-independent shock and the strength which was derived from the avoidance history.

A brief history of response contingent reinforcement for a response previously maintained by noncontingent delivery of noxious stimulation results in substantial rate elevation immediately following and for some time after a return to fixed-time response-independent shock. Hake and Campbell (1972) established baseline rates of responding by squirrel monkeys under response-independent shock delivery. Following response-independent shock, response rate was elevated using a response produced shock-free period as reinforcement.
When the reinforcement contingency was discontinued and a return made to response independent shock, responding continued to be elevated at rates two to seven times greater than occurred prior to the reinforcement history. Hutchinson (1977) and Hutchinson and Emley (1985) recorded squirrel monkeys' lever press rates under fixed-time response-independent shock. A brief, shock avoidance contingency was subsequently employed to elevate response rates. When again placed on the fixed-time response-independent shock procedure, subjects responded at elevated rates 10 to 50 times those which occurred under original fixed-time shock conditions. These rates were maintained for six to months post avoidance and showed no decrement in strength.

In summary, response contingent electric shock will, under certain conditions, maintain the behavior of which it is a consequence (Byrd, 1968; Morse & Kelleher, 1970; McKearney, 1968; Morse, Mead & Kelleher, 1967). Response-independent shock will also maintain responding with similar temporal characteristics (Hutchinson & Emley, 1972; Hutchinson, Renfrew & Young, 1971). As reinforcement histories are a commonality of response produced shock studies, it has been suggested that assessment of the contribution of these histories to performances is important (Hutchinson, 1977). In support of Hutchinson's (1977) suggestion, it has been shown that a response under antecedent stimulus control may be strengthened by consequent stimulus control (Konorski & Miller, 1937; Brogden, Lipman & Culler, 1938). In addition, responding remains at strength under conditions of response-independent shock delivery following avoidance conditioning (Kelleher, Riddle & Cook, 1963; Sidman, Herrnstein & Conrad, 1957;
Waller & Waller, 1963). A more powerful demonstration of the continuing effects of a reinforcement history on shock maintained behavior are those experiments employing an ABA design. Squirrel monkeys' lever press rates continue to be substantially increased over baseline rates whether the interposed reinforcement history is response produced time-out from shock (Hake & Campbell, 1972) or shock avoidance (Hutchinson, 1977; Hutchinson & Emley, 1985). In a given situation, both antecedent and consequent control over a response may occur and the effects of consequent control may last indefinitely after discontinuation of a contingency. There is no sound evidence that shock acts as a positive reinforcer.

The present study is a systematic replication of the ABA studies of Hutchinson (1977) and Hutchinson and Emley (1985) using both food reinforcement and avoidance of shock as the contingency.
EXPERIMENT 1

Method

Subjects

Subjects were two adult male (MC-89 and MC-106) squirrel monkeys (Saimiri sciureus) weighing 800-1000 grams. Subjects were maintained in a temperature and humidity controlled colony with free access to food and water throughout the experiment. Both subjects had experimental histories of fixed-time shock delivery during which the effect of various drugs on behavior was assessed.

Apparatus

During experimental sessions subjects were seated in a primate restraining chair (Plas Labs), restrained at the waist leaving the upper torso, arms and head free. Feet rested on a 1.75 cm bar with the tail immobilized by a stockade device (Hake & Azrin, 1963). Shock delivery was through brass electrodes resting on the shaved distal portion of the tail. Protruding from the intelligence panel in front of the subject 3.5 cm to the left of midline and 10 cm from the waist panel was a rodent lever (LVE #121-05) requiring a downward force of .20 N to operate. Midline on the intelligence panel and 23 cm above the waist panel was a button (Micro Switch #6851) 2.5 cm in diameter protruding .5 cm into the chamber and requiring a horizontal force of .98 N to deflect with a horizontal travel of .30 cm.
Located 5 cm right of midline and 28 cm from the waist panel was an amber stimulus lamp. The restraining chair was situated in a temperature controlled, sound attenuating, ventilated chamber with masking noise (84 db) provided. Illumination was by four 3 w light bulbs located on the chamber ceiling. Response counters, cumulative recorders and control equipment (Digital Equipment Corporation, R and S logic) were in an adjacent room.

Procedure

Each session was 63 minutes in duration and sessions were conducted five days a week. Subjects were placed in the restraining chair and the cleansed tail was prepared with EKG paste (Sol). Shock was 400 v ac, 200 msec and delivered through 50 k ohms resistance. The chamber was illuminated during experimental sessions. The experiment was an ABA design in which sessions of fixed-time (FT) four minute shock were followed by sessions of avoidance conditioning, then a return to FT shock. During the FT shock condition shock was delivered every four minutes irrespective of the subject's behavior, resulting in 15 shocks per session. Button and lever press rates were recorded and designated as the low or high probability response. After FT shock, a free operant avoidance procedure (Sidman, 1953) was implemented for the low probability response. A response delayed shock onset for 20 seconds (R-S interval=20 sec), and in the absence of responding shock was presented every 10 seconds (S-S interval=10 sec). At times during conditioning each subject's behavior necessitated changing R-S and S-S values and this is noted in the results.
When visual inspection of avoidance responding showed little day-to-day variability, the avoidance program was discontinued and a return made to fixed-time four minute shock. As in the first phase, shock was delivered irrespective of the subject's behavior. The lever was removed for a number of sessions for both subjects during the FT shock condition in order to assess the effects on button press rates. For MC-89 the lever was removed in the FT shock conditions before and after avoidance conditioning and in the post-avoidance FT shock condition only for MC-106. Table 1 shows the experimental conditions for both subjects.

Results

The mean response rate for blocks of five sessions were computed across the experimental conditions and these data are presented in Figure 1 for subject MC-106, and in Figure 2 for subject MC-89. Figures 1 and 2 show that for both subjects (MC-106 and MC-89) button press was the low probability response under fixed-time shock conditions. From Figure 1 it can be seen that under the original free shock condition, subject MC-106 evidenced moderate but stable rates of button pressing. In Figure 2 it can be seen that under the same conditions, responding on the button was virtually absent for subject MC-89. As can be seen from Figures 1 and 2, lever pressing occurred for both subjects during the original fixed-time shock condition. One subject's (MC-89) lever press rate for the last five sessions prior to avoidance training was 3.10 responses per minute while the other subject (MC-106) averaged 15.50 responses per minute. In
Table 1
Experimental Conditions for Experiment 1
(Subjects MC-106 and MC-89)

<table>
<thead>
<tr>
<th>Sessions</th>
<th>Experimental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC-106</strong></td>
<td></td>
</tr>
<tr>
<td>1-35</td>
<td>Fixed-time response independent shock, button force .98 N, travel 3.0 mm</td>
</tr>
<tr>
<td>40-115</td>
<td>Button press avoidance, R-S 20&quot;, S-S 10&quot;</td>
</tr>
<tr>
<td>45</td>
<td>Button feedback added (relay mounted on the back of the intelligence panel)</td>
</tr>
<tr>
<td>70</td>
<td>Button replaced with a telegraph key, button force increased across sessions from .25 to .98 N, travel from 2.5 to 3.0 mm</td>
</tr>
<tr>
<td>78</td>
<td>Telegraph key replaced with the button, .98 N force, 3.0 mm travel</td>
</tr>
<tr>
<td>80</td>
<td>R-S signal added (panel mounted amber stimulus light)</td>
</tr>
<tr>
<td>85</td>
<td>Button feedback removed</td>
</tr>
<tr>
<td>90</td>
<td>R-S signal removed</td>
</tr>
<tr>
<td>120-220</td>
<td>Avoidance discontinued, return to fixed-time response independent shock</td>
</tr>
<tr>
<td>200</td>
<td>Lever out</td>
</tr>
<tr>
<td><strong>MC-89</strong></td>
<td></td>
</tr>
<tr>
<td>1-110</td>
<td>Fixed-time response independent shock, button force .98 N, travel 3.0 mm</td>
</tr>
<tr>
<td>29-40</td>
<td>Lever out</td>
</tr>
<tr>
<td>111-275</td>
<td>Button press avoidance, initial conditions R-S 20&quot;, S-S 5&quot;. increased across sessions to R-S 20&quot;, S-S 10&quot;</td>
</tr>
<tr>
<td>130</td>
<td>Button feedback added (relay mounted on back of intelligence panel)</td>
</tr>
</tbody>
</table>
Table 1 - Continued

<table>
<thead>
<tr>
<th>Sessions</th>
<th>Experimental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>173-210</td>
<td>Button replaced with telegraph key, button force increased across sessions from .49 N to 1.32 N, travel from 1.25 to 3.0 mm</td>
</tr>
<tr>
<td>230</td>
<td>Button feedback removed</td>
</tr>
<tr>
<td>276-400</td>
<td>Avoidance discontinued, return to fixed-time response independent shock</td>
</tr>
<tr>
<td>219-383</td>
<td>Lever out</td>
</tr>
<tr>
<td>384-400</td>
<td>Lever in</td>
</tr>
</tbody>
</table>

Figures 3 and 4 sample cumulative records of lever and button pressing are presented. Records show typical performances during the noncontingent shock conditions, as well as for when the avoidance contingency was in effect. The cumulative record in Figure 3 shows that for the subject which showed stable rates of button pressing in the first fixed-time shock condition (MC-106), responding typically occurred in bursts in the middle of the shock-shock interval. Figures 3 and 4 show that for both subjects lever pressing was characterized by the absence of responding early in the shock-shock interval, and positive acceleration later in the interval with a pause in responding shortly before shock.

Acquisition of button pressing maintained by the avoidance contingency was slow for both subjects necessitating addition of response feedback, a R-S stimulus light and changes in both the R-S and S-S parameters. At times during conditioning the button was replaced with a rear mounted telegraph key such that the knob of the key
Figure 1. Five Session Means of Session Totals for Subject MC-106. Button presses are indicated by closed circles, lever presses by open circles. Five session means of the sums of lever and button presses are indicated by the closed triangles. These totals were computed for the response independent shock conditions only.
Figure 2. Five Session Means of Session Totals for Subject MC-89. Closed circles are button presses, open are lever presses.
RESPONSE INDEPENDENT SHOCK

AVOIDANCE

RESPONSE INDEPENDENT SHOCK

MC-89

RESPONSES

SESSIONS

500

LEVER OUT

LEVER OUT
Figure 3. Cumulative Records for One Subject (MC-106) Prior To, During and After Avoidance Conditioning. The first set of records is from session 85 of response independent shock, the second from session 75 of avoidance training. Shock delivery is indicated by the downward deflection of the pen. All record sets represent from the same session.
RESPONSE INDEPENDENT SHOCK
SESSION 85

MC-106

AVOIDANCE
SESSION 75

RESPONSE INDEPENDENT SHOCK
SESSION 1

SESSION 5

SHOCK

SESSION 30

BUTTON

MINUTES

LEVER
Figure 4. Cumulative Records from Sessions of Subject MC-89. The first set of records is from session 99 of response independent shock, the second set is from session 146 of avoidance training. Shock delivery is indicated by the downward deflection of the pen. All record sets represent responding from the same session.
extended through the hole previously occupied by the button and into the chamber. The amount or degree the knob protruded was altered during conditioning as acquisition of the response progressed. The specifics of these and the other experimental manipulations are found in Table 1. Response rates for the last five days of avoidance averaged 6.40 per minute button press and 2.85 per minute lever press for subject MC-89 and 37.89 button and 17.90 lever for MC-106. The cumulative records presented in Figure 3 show that pattern of button pressing during this period was for subject MC-106 alternation of bursts of responses with pauses. From Figure 4 it can be seen that the other subject (MC-89) responded steadily with little pausing. Figure 4 shows that for subject MC-89, lever pressing occurred at low rates, in bursts and usually following shocks delivered when the avoidance contingency was not met. From the record in Figure 3 it can be seen that the other subject (MC-106) emitted lever presses at a steady rate with some acceleration toward the end of a session.

Upon a return to fixed-time shock, subjects' button pressing performances were markedly elevated over baseline rates. The average rate for the five sessions immediately after the return to FT shock was 5.67 responses per minute for MC-89, and 22.24 responses per minute for MC-106. Thirty sessions after the termination of the avoidance contingency these rates had decreased to .14 and 9.19 respectively. This decrease in button pressing is illustrated in Figures 1 and 2. Figure 1 shows that subject MC-106 continued to respond at levels better than twice those evidenced during baseline. Concurrent with the gradual decline in button press rate for this
subject (MC-106) was an increment in lever press rates to levels two to three times those previously exhibited. Figure 4 shows that a fixed-interval scallop describes responding on the lever for MC-89, and in Figure 3 this same pattern is evident early in the session for MC-106 prior to transition to higher rates.

An important aspect of the pattern of lever presses shown in Figure 4 is the comparison between FT shock sessions and avoidance sessions for MC-89. During avoidance and those FT shock sessions immediately after avoidance, lever presses occurred post shock. However, during baseline FT shock sessions and those FT shock sessions occurring some time after avoidance conditioning, lever presses occurred pre shock. Thus it can be seen from Figure 4 that rates were substantially elevated following brief exposure to avoidance training, but the pattern of responding remained the same.

The effects of the lever-out conditions are evident in Figures 1 and 2. As seen in Figure 2, when the lever was removed for subject MC-89 there was no rate change in button pressing. With the reintroduction of the lever, lever pressing was seen to occur at a level lower than that which occurred in the original FT shock condition (Figure 2). From Figure 1 it can be seen that the lever-out condition resulted in an initial increase in button press rates for MC-106, followed by a return to levels as occurred prior to the removal of the lever.

For the subject showing the greatest residual response strength (MC-106), totals of lever and button presses were computed for the response independent shock conditions. Figure 1 shows that
following reinforcement there was a substantial gain in the combined strength of the two responses. An additional aspect shown by the response totals shown in Figure 1 is that while button and lever press rates were changing across sessions, there was stability in the combined number of responses emitted.

Brief Discussion

In previous studies the interposition of a history of response produced time-out from shock (Hake & Campbell, 1972) or avoidance training (Hutchinson & Emley, 1985) resulted in a substantial increase in the strength of responding produced by the noncontingent delivery of electric shock which lasted for many sessions. The present study in part replicated this effect with a response elevation due to avoidance training occurring immediately following and for some time after a return to fixed-time shock. For one subject residual strength was transitory with rates drifting down across sessions to levels comparable to baseline, while the other subject continued to show some rate elevation.

An unexpected result of the study was that as post avoidance button pressing declined in rate, there was a collateral rise in lever press rates. These rates were elevated well above levels that were previously seen under conditions of fixed-time shock. This was observed even though no reinforcement contingency was ever programmed for this manipulandum.

In Experiment 1 the effect of a history of response contingent shock avoidance on responding maintained by noncontingent shock
delivery was assessed. Experiment 2 was designed to determine the
effect of a history with a reinforcing stimulus radically different
from the physical properties of the eliciting stimulus. Several
studies (Morse & Kelleher, 1970) have shown that subsequent to a
history of response contingent food reinforcement a response con­
tingent fixed-interval schedule of shock presentation will reliably
maintain responding. In Experiment 2 lever pressing maintained by
noncontingent delivery of fixed-time shock was compared before and
subsequent to a history of lever press contingent variable food
reinforcement.
EXPERIMENT 2

Method

Subjects

Two adult squirrel monkeys (Saimiri sciureus) weighing 700-900 grams were the experimental subjects. Subjects were maintained in a temperature and humidity controlled colony with free access to water throughout the experiment. One subject (MC-105) was food deprived 16.5 hours and the other (MC-72) 17.5 hours prior to experimental sessions. Both subjects had experimental histories of fixed-time shock delivery during which the effects of various drugs were assessed.

Apparatus

The apparatus was the same as used in Experiment 1 with the exception of the following modifications. Mounted on the intelligence panel in front of the subject 9.5 cm from the waist panel and 5.0 cm to the right of midline was a rodent lever (LVE #121-05) which required a vertical force of .20 N to operate. Projecting from the intelligence panel 6.5 cm from the waist panel and on midline was a food cup to receive delivery of 45 mg pellets (Noyes).

Procedure

Sessions were conducted five days a week and each session was 63 minutes in duration. For all experimental conditions subjects
were seated in a primate restraining chair and the shaved, cleansed tail prepared with EKG (Sol) paste. Shock (400 v ac, 200 msec) was delivered to the brass tail electrodes through 50 k ohms resistance. The chamber was illuminated throughout the session. The experiment consisted of sessions of fixed-time shock followed by sessions of variable-interval (VI) food reinforcement for lever pressing with an eventual return to sessions of fixed-time shock. During the fixed-time condition shocks were delivered every four minutes regardless of subjects' behavior resulting in 15 shocks per session. For the VI food condition subjects were first trained to lever press for food by the method of successive approximations. Delivery of each pellet was accompanied by the audible click of the feeder mechanism. Once lever pressing was acquired subjects were shifted to fixed-interval and then variable-intervals of increasing length until a final schedule of VI 4' maintained responding. The VI 4' schedule consisted of 10 intervals generated using the Catania and Reynolds (1968) formula. Session length varied under acquisition of food maintained responding with the specific schedules listed in Table 2. When VI performances were stable as determined by visual inspection of daily response totals the contingent food program was discontinued and a return made to the fixed-time shock condition. Later yet, after lever pressing had again stabilized under fixed-time shock the click of the feeder mechanism was added as a consequence of responding to assess any response strength attributable to this stimulus.
Table 2

Experimental Conditions for Experiment 2
(Subjects MC-72 and MC-105)

<table>
<thead>
<tr>
<th>Sessions</th>
<th>Experimental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC-72</strong></td>
<td></td>
</tr>
<tr>
<td>1-44</td>
<td>Fixed-time response independent shock</td>
</tr>
<tr>
<td>45-170</td>
<td>Shock discontinued, variable-interval schedules of food reinforcement starting at VI 10' with a progressive shift across sessions to a final schedule of VI 4'</td>
</tr>
<tr>
<td>59</td>
<td>Lever extension added</td>
</tr>
<tr>
<td>123</td>
<td>Food deprivation changed to 85% of free feeding weight</td>
</tr>
<tr>
<td>126</td>
<td>Lever extension off</td>
</tr>
<tr>
<td>171-230</td>
<td>Food reinforcement discontinued, return to fixed-time shock</td>
</tr>
<tr>
<td>210-230</td>
<td>Feeder click added</td>
</tr>
<tr>
<td><strong>MC-105</strong></td>
<td></td>
</tr>
<tr>
<td>1-45</td>
<td>Fixed-time response independent shock</td>
</tr>
<tr>
<td>46-206</td>
<td>Shock discontinued, variable interval schedules of food reinforcement starting at VI 10' with a progressive shift across sessions to a final schedule of VI 4'</td>
</tr>
<tr>
<td>84</td>
<td>Lever extension added</td>
</tr>
<tr>
<td>125</td>
<td>Food deprivation changed to 85% of free feeding weight</td>
</tr>
<tr>
<td>151</td>
<td>Lever extension off</td>
</tr>
<tr>
<td>207-320</td>
<td>Food reinforcement discontinued, return to fixed-time shock</td>
</tr>
<tr>
<td>218-237</td>
<td>Feeder click added</td>
</tr>
<tr>
<td>281-320</td>
<td>Feeder click added</td>
</tr>
</tbody>
</table>

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Results

Mean response rates for blocks of five sessions were computed across the experimental conditions and these are shown in Figure 5 for MC-72 and in Figure 6 for MC-105. Response rates for the last five sessions of fixed-time shock were .02 responses per minute for MC-72 and .14 responses per minute for MC-105. In Figure 7 sample cumulative records of lever pressing during the experimental conditions are presented for both subjects. The low rates of responding which occurred during the original fixed-time shock condition preclude description of temporal patterning. However, it can be seen from Figure 7 that for the subject which did respond (MC-105) responses were confined to the pre-shock period.

As acquisition of food maintained lever pressing was slow to develop, a lever extension measuring 6.5 cm x 3.2 cm x .30 cm was at times employed. In addition to this, changes were made in deprivation levels for both subjects. These changes as well as the experimental conditions are found in Table 2. Average rates for the last five sessions of VI 4' food reinforcement were 1.98 responses per minute for MC-72 and 5.72 responses per minute for MC-105. The cumulative records in Figure 7 show that for both subjects responding was typical of that generated by VI food schedules. Some post reinforcement pausing was in evidence for MC-195 and some post reinforcement bursting for MC-72. The data presented in Figures 5 and 6 show that rates markedly declined with a return to fixed-time shock and quickly approximated levels occurring in the original fixed-time shock.
Figure 5. Five Session Means of Lever Presses for Subject MC-72 across All Experimental Conditions.
Figure 6. Five Session Means of Lever Presses for Subject MC-105 across All Experimental Conditions. During the response independent shock condition which followed variable-interval food reinforcement the click of the feeder mechanism was added as a consequence of lever pressing during sessions 218-237 and 281-320.
Figure 7. Sample Cumulative Lever Press Records for Subjects under Fixed-Time Shock Conditions Prior to Variable-Interval Food Reinforcement (session 40 for MC-72 and Session 41 for MC-105) and for Some Sessions After. Typical VI 4' food performance is also shown (session 121, Mc-72; session 120, Mc-105). The downward slash of the pen indicates shock (response independent shock) or food variable-interval food.
LEVER PRESSES

RESPONSE INDEPENDENT SHOCK

MC-72
SESSION 40

MC-105
SESSION 41

VI 4' FOOD

SESSION 121

SESSION 120

RESPONSE INDEPENDENT SHOCK

SESSION 5

SESSION 30

FEEDER CLICK

MINUTES
condition. Some sustained though negligible rate elevation over levels in the original fixed-time shock condition did occur for subject MC-72. The addition of the click of the feeder mechanism as a consequence of lever pressing had an immediate effect on response rates. Figure 5 shows that subject MC-72 showed an increase followed by a gradual decline in rate under this condition. Average lever press rates for the period in which the feeder click was a consequence of responding were .14 responses per minute for MC-72, compared with a mean rate of .11 responses per minute in the previous 20 sessions. From Figure 7 it can be seen that responding for this subject characteristically occurred during the first minute after shock. The other experimental subject (MC-105) continued to respond at levels substantially above those generated in the absence of the stimulus. Rates averaged 1.13 responses per minute during the first period of feeder click, compared with .06 responses per minute in the prior 20 sessions. Figure 7 shows that for MC-105 responding was generally confined to the middle of the shock-shock interval. The rate elevating effect of the click of the feeder mechanism was replicated for MC-105 with the removal and then return of the stimulus as a consequence of responding (Figure 6).

Brief Discussion

A history of response contingent variable-interval food reinforcement did not cause appreciable sustained responding when conditions were later returned to fixed-time electric shock. Acquisition of lever pressing under control of response contingent food delivery was
slow, necessitating changes in food deprivation levels and in the response manipulandum. During this period direct observation of subjects revealed the assumption of a position best described as resting with the head placed in the far corner of the restraining chair. This inactivity interfered with experiment conditioning and would seem to indicate that pellet delivery failed to serve as reinforcement. However, food pellets were readily consumed in and outside of the experimental setting. Another possibility is that extensive histories of fixed-time shock resulted in acquisition of repertoires characterized by the occurrence of behavior closely timed to shock delivery and low levels of the absence of responding at other times in the shock-shock interval.

In Experiment 1 one subject showed some continued rate elevation under fixed-time shock following response strengthening by a shock avoidance history. In the present experiment, lever press rates were elevated during conditions of variable-interval food reinforcement. However, this effect did not continue and fixed-time shock responding decreased across sessions to near baseline levels. The absence of responding may have been due to conditions during food reinforcement being dissimilar enough from those during fixed-time shock so as to hinder transfer of response strength from one condition to the other.

An interesting result of the present study was the effect on responding of a stimulus historically paired with food. While for one subject the contingent delivery of the click of the feeder mechanism produced an increase and then gradual decline in response
rate, the other subject's responding continued to be elevated. An
effect of simple conditioned reinforcement would account for the sub-
ject showing the temporary increase in responding across sessions.
If conditioned reinforcement were the only property of the stimulus,
the other subject's response rate would be expected to show a similar
decline in rate. The second subject continued to show rate enhance-
ment as a result of consequent presentation of the feeder stimulus
and this suggests that conditioned reinforcement may not have been
the only variable operating. As the effect of the click stimulus
was not assessed prior to pairing to food delivery, it is not possi-
bile to rule out entirely the possibility that this contingent stimulus
possessed inherent reinforcing properties.
GENERAL DISCUSSION

The present experiments were designed to assess the effects of a history of reinforcement on a response pattern established by fixed-time noncontingent shock delivery. In the first experiment it was found that following exposure to a schedule of free operant avoidance, the reinforced response was elevated in rate immediately following and for some time after a return to noncontingent shock. This rate enhancement was seen for the response which was reinforced (button press), as well as for the response which was not (lever press). The rate increase in button pressing seen following free operant avoidance gradually diminished with one subject showing some continued rate enhancement. Both subjects' lever press rates showed continued rate elevation following avoidance training, even though there was never reinforcement for this response. Lever press rates were higher than button press rates under conditions of FT shock prior to avoidance training and also under FT shock conditions some time after avoidance training. During free operant avoidance, button press rates were higher than lever press rates. One thing which changed across sessions and conditions was the probability of responding on one response option or the other. This indicated that the effects of avoidance training were twofold: response strengthening as indicated by overall rate increases, and a change in the probability of occurrence of one response or the other. The probability of a response (lever or button pressing) was changed from baseline by the implementation of the
avoidance contingency. Following a return to FT shock conditions the probability of occurrence of one response or the other gradually shifted across sessions with an eventual return to the allocation of responses between the two options as had previously occurred during baseline. However, as indicated by the response totals seen in Figure 1, there was no similar return in total response strength to baseline levels. A final point about the first experiment is that the avoidance response was slow to be acquired. Prior exposure to noncontingent shock may slow the rate at which a response to escape shock is acquired (Dinsmoor & Campbell, 1956). Since subjects had extensive histories of noncontingent shock, this may account for the difficulties encountered.

In the second experiment the use of reinforcement with physical properties different from the eliciting stimulus did not result in long-term changes in shock produced responding. Subjects' behavior was slow to come under the control of the food reinforcement contingencies and as suggested earlier this may have been a function of extensive noncontingent shock histories. While an increase in rate was slow to develop, responding was substantially elevated prior to a return to fixed-time response independent shock. Why then was this increase not sustained for any appreciable time following training? One possible explanation is that conditions during sessions of food reinforcement were unlike those which prevailed during shock. Response strengthening which did occur may not have readily transferred from one condition to the other. In operant research, stimuli which occur in the context of the experimental setting have been shown
to exert a powerful influence on behavior (Mackintosh, 1977). A similar effect may account for the present results. A stimulus historically paired with food reinforcement, when delivered as a consequence of responding, elevated lever press rates. While this stimulus would be expected to have conditioned reinforcing properties, rate enhancement may also have been due to the altered antecedent stimulus conditions such that they more closely approximated those which occurred during food reinforcement. For one subject the effect of this stimulus did not decrease across sessions, and this was replicated with the removal and subsequent reintroduction of the stimulus. If the stimulus had conditioned reinforcing properties alone, the effect would have weakened across sessions as there were no additional pairings with the primary reinforcer, food. Another possible explanation is that the auditory stimulus served as a sensory reinforcer. The response contingent delivery of sensory stimuli has been shown to generate responding, and the reinforcing efficacy of these stimuli is altered by motivational variables (see Kish, 1966, for a review). Response contingent delivery of the click of the feeder mechanism may have acted as auditory sensory reinforcement (Butler, 1957). Strong motivational variables that may have contributed to this performance are food deprivation (Kish, 1966). As no assessment of the inherent reinforcing capacities of this stimulus was made during baseline, no clear answer is available.

Historical exposure to reinforcement may cloud attempts to delineate the variables contributing to performances maintained by contingent brief electric shock. That noncontingent shock generates
considerable amounts of behavior is well documented, as are the lasting effects of reinforcement. The present studies and others (Hake & Campbell, 1972; Hutchinson, 1977; Hutchinson & Emley, 1985) show reinforcement having considerable residual response elevating effects on behavior. It is reasonable to question whether the same residual reinforcement effects are a variable contributing to fixed-interval shock performances.

A final point which needs be addressed is the difference in response rates between studies of response-produced shock and those of response independent shock. Response rates have been lower under conditions of noncontingent than contingent shock following reinforcement. Where Hutchinson and Emley (1985) found that, following exposure to an avoidance procedure, subjects responded approximately 2 to 9 times per minute under FT 4' shock, McKearney (1968) showed rates of approximately 15 to 25 responses per minute under a FI 10' schedule of shock presentation, and McKearney (1969) approximately 25 to 100 responses per minute under fixed-interval shock schedules ranging from FI 1' to FI 10'. With noncontingent shock Hake and Campbell (1972) obtained rates of approximately 45 to 60 responses per minute, but used a short shock-shock interval (FT 30').

While rates are not as high under noncontingent shock, variables other than the presence or absence of a contingency may account for this difference. In the Hutchinson and Emley (1985) and the present studies baseline rates were low due to subject selection or through choice of a particular response manipulandum. Higher initial rates may have resulted in proportionally higher rates following reinforcement.
There is need for additional studies to assess the different effects of such variables as shock intensity, interval length, response manipulandum, type of response strengthening procedure and duration of exposure to reinforcement.
BIBLIOGRAPHY


