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# ELECTRIC SHOCK PRODUCED DRINKING IN THE SQUIRREL MONKEY

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Squirrel monkeys were periodically exposed to brief electric tail shocks in a test environment containing a rubber hose, response lever, and a water spout. Shock delivery produced preshock lever pressing and postshock hose biting. Additionally, all subjects displayed licking responses following postshock biting-attack episodes. Further experiments showed that licking was: (1) influenced by hours of water deprivation; (2) drinking behavior; (3) the direct result of shock delivery; and (4) developed spontaneously in naive subjects with or without opportunities for hose biting or lever pressing. Removing the opportunity to attack increased postshock drinking. A noxious environmental stimulus that causes aggression can also produce drinking.

*Key words:* drinking, aggression, response-independent shock, licking, lever press, biting, squirrel monkey

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If a brief electric shock is delivered to a squirrel monkey, the subject may vigorously attack both animate and inanimate objects. The behavior occurs in a predictable temporal pattern characterized by maximum attack immediately after the shock and a subsequent gradual decrease over time (Azrin, Hutchinson, and Hake, 1963; Azrin, Hutchinson, and Sallery, 1964; Hutchinson, Azrin, and Hake, 1966).

If initially neutral stimuli repetitively precede electric shock, they will also elicit attack (Hutchinson, Renfrew, and Young, 1971). Aggressive behavior is thus conditionable through associative or Pavlovian learning processes. However, nonattack reactions, including the manual manipulative topographies typical of escape avoidance-type behaviors are prepotent during conditional stimuli, and occur each time the conditional stimulus occurs, even when the response neither terminates nor prevents the stimulus (Hutchinson, 1976; Hutchinson *et al.*, 1971; Hutchinson and Emley, 1972). Where repetitive instances of conditional stimulation precede unconditional stimulation, both the escape avoidance-like performances and attack behaviors occur (Emley and Hutchinson, 1972; Hake and Campbell, 1972; Hutchinson, 1973; Hutchinson *et al.*, 1971).

The present experiments found that another behavioral sequence, *i.e.*, drinking, occurs during shock-delivery programs and that such drinking responses bear a predictable temporal and intensive relationship to shock and to those other behavioral sequences previously reported to occur under such conditions.

## GENERAL METHOD

### *Subjects*

Ten male, adult squirrel monkeys, weighing 600 to 1000 g, were individually housed and fed Wayne monkey diet. Water was available from a bottle mounted on the cage. For certain experiments, where noted, naive subjects were used.

### *Apparatus*

Primate restraint chairs (Plas Labs, Lansing, MI) restrained the monkeys at the waist. Shock was delivered to the tail, which was immobilized by a stockade device, through elec-

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trodes resting on its shaved distal portion (Hake and Azrin, 1963). The tail was cleansed and prepared with EKG paste before each session. Suspended 20 cm above the waist panel at shoulder level 9 cm in front of the monkey (10 cm from the front panel) and extending 20 cm from left to right walls of the chamber was an 18-mm (outer diameter) latex rubber bite hose (Hutchinson *et al.,* 1966). The hose was connected to an Air Wave switch (Tapeswitch Corp.), which was calibrated to record bite responses. A response lever (Lehigh Valley Electronics # 1352) was mounted 10 cm above the waist plate on the lower-left side of the front panel 5 cm from the left wall of the chamber. A lever press of 0.20 N of force was required to record a response (Hutchinson *et al.,* 1971). The restraint chair was enclosed in a ventilated and acoustically shielded outer chamber.

To measure drinking, a water bottle and stainless-steel drink tube were mounted outside the left wall of the chamber 17 cm above the waist panel at chest level and 4 cm forward from the subject's torso. The drink tube was connected to a drinkometer touch circuit electrically isolated from all other voltage sources. The drink tube protruded 3 mm into the chamber. All licks were recorded on counters and cumulative recorders. The fluid reservoir containing tap water was calibrated and amounts of water dispersed during the session could be recorded.

### *Procedure*

Electric shock (400 V ac, 200 ms) was delivered through a series resistance of 50 K ohms to the tail every 4 min on a response-independent, fixed-time schedule, for a total of 15 shocks per 64-min session. Bites and lever presses were recorded on cumulative recorders, event recorders, and counters. All solid-state programming and recording equipment was located in an adjoining room. Test sessions were conducted five days a week.

The water bottle was removed from the subject's home cage for a specified number of hours following the previous session. Under longer periods of water deprivation, subjects would, when placed in the test chamber, immediately drink 2 to 6 cc of water from the spout during tail preparation and check-out routines before a session began. Drinking ceased after 30 to 90 sec, at which time the test session was begun.

## EXPERIMENT I: DRINKING FOLLOWING ELECTRIC-SHOCK PRESENTATION UNDER SEVERAL DEPRIVATION CONDITIONS

### *Subjects*

Monkeys MC-12, MC-22, and MC-30, which had been exposed to a response-independent shock schedule for approximately 2 yr, were used.

### *Procedure*

Initially, subjects were given 15 tail shocks in a 64-min session. After several weeks, subjects were water deprived for 21 hr before succeeding sessions and a water bottle was added to the experimental chamber. Following these tests, two subjects (MC-12, MC-30) were exposed on different days to different levels of water deprivation for four to 10 sessions. Deprivation levels were changed in a counterbalanced sequence and were altered when behavior at a given level appeared stable.

### Results and Discussion

The response-independent shock schedule generated a temporal and topographic response pattern of biting after shock and lever pressing before shock. When subjects were water deprived, and the water bottle added to the chamber, the temporal pattern of licking that emerged within three to eight sessions was similar for each subject. Figure 1 illustrates this response pattern with a sample cumulative record for Subject MC-12. Licks occurred after shock and bites. Three independent observers never noted any biting or manual contact with the drinking tube, so that electrically recorded licks, corresponded to visually observed licks. Figure 2 illustrates the temporal pattern of responding for each subject throughout the intershock interval on the last day before the drink tube was available, and for Day 1 and Day 5 after water was available. Though these results showed that licking occurred during a shock-delivery sequence, it was not certain that licking reflected fluid ingestion. To test whether the observed licking possessed one characteristic of drinking and would be influenced by water deprivation, additional water-deprivation tests were conducted with MC-12 and MC-30. Conditions of water deprivation, number of sessions at each level for each subject, and frequency of biting, licking, and lever

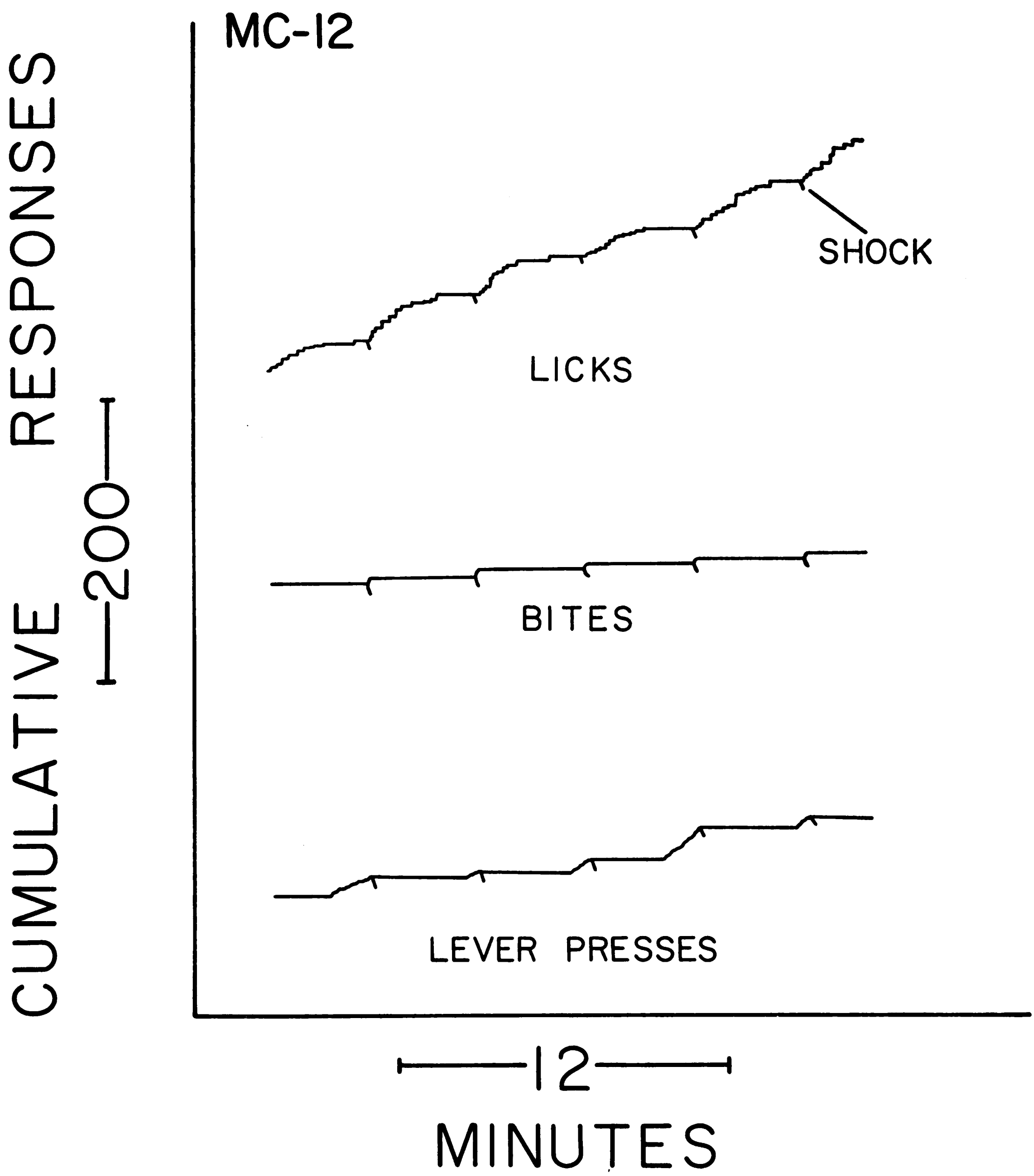


Fig. 1. A portion of three simultaneous cumulative records for a subject during a single shock session, illustrating the temporal pattern of lever pressing, hose biting, and licking.

pressing are listed in Table 1. For both subjects, increased hours of deprivation increased licking, and decreased deprivation reduced licking. Thus, licking was influenced by water deprivation, a factor that also is known to influence drinking. That the occurrence of licking, biting, and lever pressing was not fully independent may be seen from the fact that increased drinking under longer periods of water deprivation corresponded to lower rates of biting and (for MC-12) lever pressing.

## EXPERIMENT II: DEPENDENCE OF DRINKING UPON SHOCK

Though Experiment I demonstrated that licking occurred with electric-shock presentation and appeared related to shock delivery,

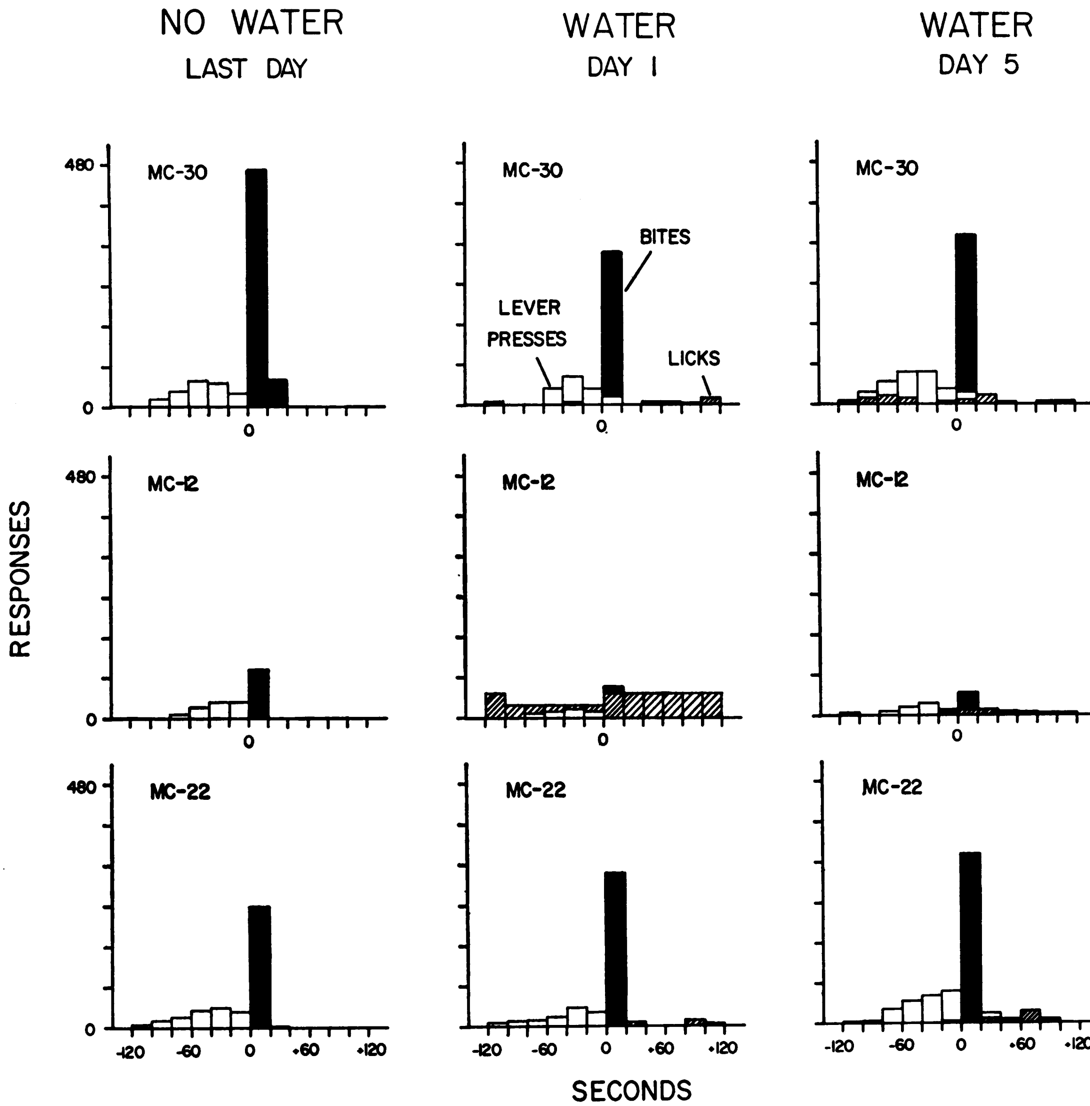


Fig. 2. The temporal distribution of lever pressing, hose biting, and drink-tube licking before drink-tube presence and on the first and fifth days after the drink tube was introduced for three subjects. Shock occurred at time zero (0) sec. The upper limit of each shaded portion of each bar indicates the session response total for the specific response depicted.

assessment of the relevance of shock to licking required systematic manipulation of shock. Also, to relate licking to water ingestion (drinking), several subjects were given conditions of shock, no shock, and shock, during which licking, fluid dispersement, and body-weight changes were observed.

*Subjects*

Monkeys MC-12, MC-22, MC-30, MC-74, and MC-75 served.

*Procedure*

Subjects were tested successively in a series of sessions with shock, without shock, and shock again. In sessions without shock, the animal's tail was prepared for shock, but the shock generator was turned off.

Three subjects (MC-22, MC-30, MC-74) were tested at 21-hr water deprivation; two (MC-12 and MC-75) were tested at 4-hr water deprivation.

**Table 1**

**Effect of Water Deprivation on Biting, Licking, and Lever Pressing**

| *Subject* | *Dep. (hr)* | *Session* | *Bites* | | *Licks* | | *Lever Presses* | |
|---|---|---|---|---|---|---|---|---|
| | | | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* |
| MC-12 | 2 | 8-13 | 71 | 69-84 | 33 | 2-73 | 122 | 97-157 |
| | 21 | 14-22 | 44 | 23-63 | 1019 | 249-1739 | 98 | 66-133 |
| | 2 | 23-28 | 77 | 70-86 | 2 | 0-6 | 152 | 83-208 |
| | 4 | 29-32 | 68 | 64-72 | 401 | 289-488 | 161 | 151-180 |
| MC-30 | 21 | 27-31 | 334 | 312-363 | 62 | 47-87 | 130 | 105-170 |
| | 3 | 32-37 | 389 | 275-472 | 25 | 9-44 | 136 | 63-204 |
| | 21 | 38-48 | 337 | 299-380 | 35 | 23-55 | 156 | 85-243 |

Content of the fluid reservoir in the test chamber for Subjects MC-22, MC-74, and MC-75 was a mixture of water and powdered orange flavoring; for Subjects MC-12 and MC-30, the reservoir contained tap water.

For Subjects MC-22, MC-74, and MC-75, content of the drinking reservoir was measured before the first shock of the session and at the end of the session. Each subject and the individual absorbent disposable refuse-tray paper used in each session was weighed before and after each test session. The combined before-after weight difference reflected the subject's weight change during a session, adjusted for urine and feces elimination. Home-cage water consumption in the postsession, predeprivation period was also recorded.

## Results and Discussion

Table 2 presents data for the last four sessions of the first shock series, the first four sessions without shock, and the first four sessions with shock re-instated. Sessions 230, 231, 232 for MC-22, 218, 219, 220 for MC-74; and 198 to 203 for MC-75 are excluded because water-deprivation conditions varied from specified values. Also, only one shock-absent session and two return-to-shock sessions were conducted for MC-12. For each of the five subjects, elimination of shock virtually eliminated (with two

**Table 2**

**Effect of Shock Delivery on Biting, Licking, and Lever Pressing**

| | *Session* | *Bites* | | *Licks* | | *Lever Presses* | |
|---|---|---|---|---|---|---|---|
| | | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* |
| 21-Hr Water Deprivation | | | | | | | |
| MC-30 | | | | | | | |
| Shock present | 96-99 | 318 | 292-329 | 37 | 26-53 | 28 | 22-32 |
| Shock absent | 100-103 | 0 | | 1 | 0-2 | 4 | 0-10 |
| Shock present | 104-107 | 305 | 205-395 | 49 | 33-71 | 24 | 19-27 |
| MC-22 | | | | | | | |
| Shock present | 221-225 | 194 | 261-128 | 74 | 65-90 | 118 | 158-104 |
| Shock absent | 226-229 | 0 | | 4 | 2-6 | 0 | |
| Shock present | 233-236 | 197 | 175-222 | 90 | 55-122 | 82 | 69-109 |
| MC-74 | | | | | | | |
| Shock present | 210-213 | 45 | 25-50 | 220 | 187-281 | 2399 | 2054-2880 |
| Shock absent | 214-217 | 0 | 0-2 | 6 | 1-11 | 700 | 448-1047 |
| Shock present | 221-224 | 61 | 58-65 | 298 | 211-457 | 2289 | 1636-2653 |
| 4-Hr Water Deprivation | | | | | | | |
| MC-12 | | | | | | | |
| Shock present | 29-32 | 68 | 64-72 | 401 | 289-488 | 161 | 151-180 |
| Shock absent | 33 | 0 | | 9 | | 2 | |
| Shock present | 34-35 | 70 | 65-74 | 420 | 393-446 | 84 | 42-126 |
| MC-75 | | | | | | | |
| Shock present | 190-193 | 753 | 679-832 | 51 | 23-75 | 6 | 3-9 |
| Shock absent | 194-197 | 502 | 188-673 | 4 | 3-5 | 0 | |
| Shock present | 204-207 | 1419 | 1188-1560 | 77 | 59-100 | 6 | 4-8 |

Table 3

Effect of Shock Delivery on Licking, Fluid Dispersement, and Subject Weight Gain

| | | *Licks* | | *Session (cc) Fluid Intake/* | | *Weight Gain/ Session (gms)* | | *Cage Fluid Intake/Day (cc)* | | *Total Fluid Intake/Day (cc)* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Session* | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* |
| 21-HR WATER DEPRIVATION | | | | | | | | | | | |
| MC-22 | | | | | | | | | | | |
| Shock present | 221-225 | 74 | 65-90 | 36 | 29-44 | 21 | 15-29 | 24 | 18-38 | 60 | 49-82 |
| Shock absent | 226-229 | 4 | 2-6 | 16 | 2-24 | 7 | −6, 19 | 55 | 32-89 | 71 | 46-93 |
| Shock present | 233-236 | 90 | 55-122 | 41 | 26-50 | 25 | 22-28 | 20 | 8-37 | 61 | 34-85 |
| MC-74 | | | | | | | | | | | |
| Shock present | 210-213 | 220 | 187-281 | 41 | 30-48 | 15 | 10-18 | 43 | 32-60 | 84 | 74-108 |
| Shock absent | 214-217 | 6 | 1-11 | 31 | 18-42 | 18 | 14-23 | 45 | 34-61 | 68 | 61-76 |
| Shock present | 221-224 | 298 | 211-457 | 37 | 34-44 | 26 | 17-46 | 43 | 20-57 | 78 | 54-91 |
| 4-HR WATER DEPRIVATION | | | | | | | | | | | |
| MC-75 | | | | | | | | | | | |
| Shock present | 190-193 | 51 | 23-75 | 29 | 26-32 | 21 | 10-34 | 83 | 63-92 | 111 | 95-123 |
| Shock absent | 194-197 | 4 | 3-5 | 21 | 20-24 | 9 | 1-14 | 76 | 42-99 | 98 | 62-123 |
| Shock present | 204-207 | 77 | 59-100 | 32 | 26-36 | 30 | 21-48 | 72 | 64-81 | 104 | 90-112 |

exceptions) biting, lever pressing, and licking. Exceptions were that lever pressing decreased gradually for MC-74 and biting decreased gradually for MC-75. With return-to-shock conditions, biting, lever pressing, and licking resumed immediately.

Reservoir fluid dispersement followed the pattern observed for licking. Table 3 shows that fluid dispersement decreased when shock was terminated, and increased when shock was re-instated. Each of the three subjects showed generally consistent weight gains following test sessions. Increases and decreases in measured fluid dispersement, upon removal and re-instatement of shock conditions, corresponded to increases and decreases in subject weight gains in eight of nine cases. The single discordance was the relatively lower weight gain during initial shock conditions for MC-74.

For Subject MC-22 (21 hr water deprived) water dispersement in the 2-hr postsession home-cage period was inversely related to fluid dispersement in the test chamber. The relatively greater fluid dispersement during shock-testing sessions was followed by relatively smaller fluid dispersement after the subject was in the home cage. In contrast, MC-74 frequently increased total daily intake when shocks were delivered. For MC-75, no effect of session fluid dispersement was observed in the 19-hr postsession period when water was available. Total daily intake sometimes increased on days when shocks were delivered.

These results collectively indicate that the observed licking was fluid-ingestion behavior, *i.e.,* drinking, and that the drinking was produced by shock or some shock-related conditions.

## EXPERIMENT III: DEVELOPMENT OF SHOCK-PRODUCED DRINKING IN NAIVE SUBJECTS

The subjects in Experiments I and II had been tested for months or years under conditions involving shock and several response opportunities. Perhaps the new opportunity to engage in yet another response (drinking) could, through a process of chaining between drinking and an already prepotent response, account for the observed drinking behavior. For this reason, naive subjects were tested with the opportunity to attack, drink, and lever press present in the earliest sessions. To control for possible response interaction possibilities, several additional naive subjects were tested with no response options other than drinking.

### *Subjects*

Six naive, adult male squirrel monkeys (MC-74, MC-78, MC-96, MC-100, MC-101, MC-103) served. Subject MC-74 was tested under the present conditions before those described in Experiment II.

### *Procedure*

Each subject was habituated to the colony living conditions for several months. During early sessions, no shocks were delivered. When it appeared that licking reactions were stable or absent, shock deliveries were begun. All subjects, except MC-101, were 21-hr water deprived at the beginning of each session. Subject MC-101 had 4-hr water deprivation.

### Results and Discussion

Table 4 shows that drinking developed or increased markedly when shock was introduced for each of the six subjects. Within two shock sessions, each subject showed frequent drinking and (where possible) biting. Though lever pressing developed rapidly for one subject (MC-74), the other two still pressed infrequently after 20 to 30 shock sessions.

The emergence of drinking and biting when shock was introduced for MC-74, MC-78, and MC-96 argues against the interpretation that drinking observed in Experiments I and II depended on an established biting-attack performance. Event records of the two performances revealed no predictable interactions, except that drinking almost always occurred after biting, even in earliest shock sessions. The results for Subjects MC-100, MC-101, and MC-103, where no other response options were ever available, were identical to those obtained in the multiple response situation. Thus, drinking and biting are each independently produced by shock. Nevertheless, it is not possible to exclude fully some form of interaction of drinking responses with biting responses.

## EXPERIMENT IV: EFFECTS OF REMOVAL OF THE OPPORTUNITY TO ATTACK UPON SHOCK-PRODUCED DRINKING

Experiments I to III demonstrated that drinking was produced by shock. In the major

Table 4

Development of Shock-Produced Drinking in Naive Subjects

| | Session | *Bites* Mean | *Bites* Range | *Licks* Mean | *Licks* Range | *Lever Presses* Mean | *Lever Presses* Range |
|---|---|---|---|---|---|---|---|
| 21-Hr Water Deprivation | | | | Hose and Lever Present | | | |
| MC-74 | | | | | | | |
| Shock absent | 1-2 | 1 | 0-2 | 6 | 0-12 | 17 | 4-31 |
| Shock present | 3-7 | 104 | 0-197 | 79 | 42-132 | 210 | 4-522 |
| Shock present | 8-12 | 44 | 44-49 | 147 | 102-216 | 670 | 304-1004 |
| Shock present | 13-17 | 71 | 55-82 | 190 | 136-247 | 753 | 387-1216 |
| MC-78 | | | | | | | |
| Shock absent | 1-13 | 6 | 0-44 | 0 | 0-7 | 10 | 0-111 |
| Shock present | 14-18 | 752 | 431-1098 | 30 | 11-77 | 21 | 0-62 |
| Shock present | 19-23 | 700 | 607-808 | 14 | 8-19 | 26 | 13-49 |
| MC-96 | | | | | | | |
| Shock absent | 1-12 | 56 | 0-316 | 0 | 0-3 | 4 | 0-42 |
| Shock present | 13-17 | 571 | 0-1670 | 14 | 1-28 | 0 | 0-2 |
| Shock present | 18-22 | 1297 | 838-1637 | 31 | 25-35 | 0 | |
| Shock present | 23-27 | 764 | 388-1150 | 38 | 28-43 | 0 | |
| MC-103 | | | | Hose and Lever Absent | | | |
| Shock absent | 1-5 | | | 0 | | | |
| Shock present | 5-10 | | | 4 | 0-10 | | |
| Shock present | 11-15 | | | 6 | 0-25 | | |
| Shock present | 16-20 | | | 35 | 0-153 | | |
| Shock present | 21-25 | | | 788 | 483-1366 | | |
| MC-100 | | | | | | | |
| Shock absent | 1-2 | | | 18 | 5-31 | | |
| Shock present | 3-7 | | | 28 | 5-38 | | |
| Shock present | 8-12 | | | 60 | 31-94 | | |
| Shock present | 13-17 | | | 78 | 63-102 | | |
| Shock present | 18-22 | | | 70 | 43-83 | | |
| 4-Hr Water Deprivation | | | | | | | |
| MC-101 | | | | | | | |
| Shock absent | 1-9 | | | 13 | 2-31 | | |
| Shock present | 10-14 | | | 57 | 52-64 | | |
| Shock present | 15-19 | | | 73 | 59-102 | | |
| Shock present | 20-24 | | | 52 | 47-85 | | |

portion of these experiments, subjects also engaged in biting attack. Each subject demonstrated a pattern of biting attack immediately after shock and drinking after biting attack. Since drinking was nearly always preceded by episodes of biting attack, the two performances may not have been independent. The present experiment attempted to determine what temporal patterning and rate characteristics drinking responses might assume when the biting-attack opportunity was manipulated.

### *Subjects*

Three male, adult squirrel monkeys (MC-22, MC-30, MC-75), each of which had been tested in several experiments in the series and in earlier response-independent shock experiments, served.

### *Procedure*

All apparatus was as described in the general method section. Subjects had consecutive groups of sessions when the rubber bite hose was present, absent, and then again present. In most cases, five sessions were conducted with each condition. If a question of behavioral stability arose, additional sessions were conducted before changing conditions.

## Results and Discussion

Table 5 presents data on biting, licking, and lever pressing per session for the last five sessions of hose present, hose absent, and the final hose-present condition. Removal of the hose caused a pronounced increase in drinking either immediately or after several days. When

Table 5

Effect of Removal of Opportunity to Attack upon Shock-Produced Drinking

| | | *Bites* | | *Licks* | | *Lever Presses* | |
|---|---|---|---|---|---|---|---|
| | *Session* | *Mean* | *Range* | *Mean* | *Range* | *Mean* | *Range* |
| MC-30 | | | | | | | |
| Hose present | 44-48 | 327 | 292-366 | 30 | 23-38 | 197 | 105-243 |
| Hose absent | 56-60 | 0 | | 62 | 29-92 | 80 | 61-93 |
| Hose present | 76-80 | 327 | 299-346 | 26 | 18-34 | 34 | 25-44 |
| MC-22 | | | | | | | |
| Hose present | 49-53 | 275 | 245-299 | 36 | 18-63 | 216 | 202-244 |
| Hose absent | 74-78 | 0 | | 67 | 26-90 | 395 | 297-461 |
| Hose present | 85-88 | 173 | 143-218 | 64 | 23-105 | 222 | 175-249 |
| MC-75 | | | | | | | |
| Hose present | 48-52 | 546 | 357-764 | 109 | 71-175 | 0 | |
| Hose absent | 86-90 | 0 | | 191 | 152-236 | 22 | 11-39 |
| Hose present | 104-108 | 580 | 483-716 | 69 | 33-112 | 1 | 0-1 |

the hose was replaced, drinking progressively decreased for Subjects MC-30 and MC-75, but remained elevated for Subject MC-22. Lever pressing increased during hose absence for MC-22 and MC-75. When the opportunity to attack was re-instated, lever pressing decreased for each subject.

The increased drinking during absence of the bite hose occurred immediately after shock, the period when bites occurred with the hose present. Figure 3 illustrates this effect. Subjects MC-22 and MC-30 each displayed preshock lever pressing and postshock biting attack, followed by drinking. Removal of the bite hose increased, for each subject, postshock drinking and postshock lever pressing. Lever pressing tended to occur first, followed by drinking. Lever pressing was not "displaced" biting. Visual observation showed that subjects engaged in a rapid flurry of manual lever presses, followed by licking on the drink tube. Subjects did not bite the response lever or any other part of the chamber. This postshock lever pressing during hose absence was less frequent than biting during the hose-present condition. Previous experiments have shown that removing the opportunity to attack increases postshock lever pressing (Hake and Campbell, 1972; Hutchinson and Emley, 1972). Additionally, drinking began earlier following shock at the cessation of lever pressing.

Subject MC-75 did not display preshock lever pressing but did engage in preshock biting attack. The delayed development of lever pressing has been reported earlier (Hutchinson *et al.,* 1971; Hutchinson and Emley, 1972). Here also, elimination of the bite opportunity increased frequency of drinking in the postshock period. The peak in drinking occurred 20 to 40 sec after shock, as it had during the previous condition when the opportunity to attack had been present. Lever pressing developed during this period of hose absence. Most lever responses occurred during the preshock period and more than 120 sec after a previous shock.

The results confirmed those of Experiment III and demonstrated that drinking was not dependent on either biting or lever pressing. Alternatively, the frequent reduction of drinking responses during opportunities to attack, and the occurrence of biting or lever pressing (during hose-absent conditions) before drinking illustrated that both biting and lever pressing were prepotent, relative to drinking. Yet, even where biting attack and escape avoidance-like performances were present, drinking occurred following shock.

## GENERAL DISCUSSION

The results demonstrated a direct relation between electric shock delivery and drinking. Several previous experiments have found changes in water consumption after exposure to noxious stimulation with other procedures (Levine, 1965; Moyer and Baenninger, 1963; Segal and Oden, 1969; Williams and Teitelbaum, 1956).

Deaux and Kakolewski (1970) reported that both handling and mechanical rotation increased drinking by rats. Further experiments led these investigators to conclude that stress, anxiety, or emotional excitement increased

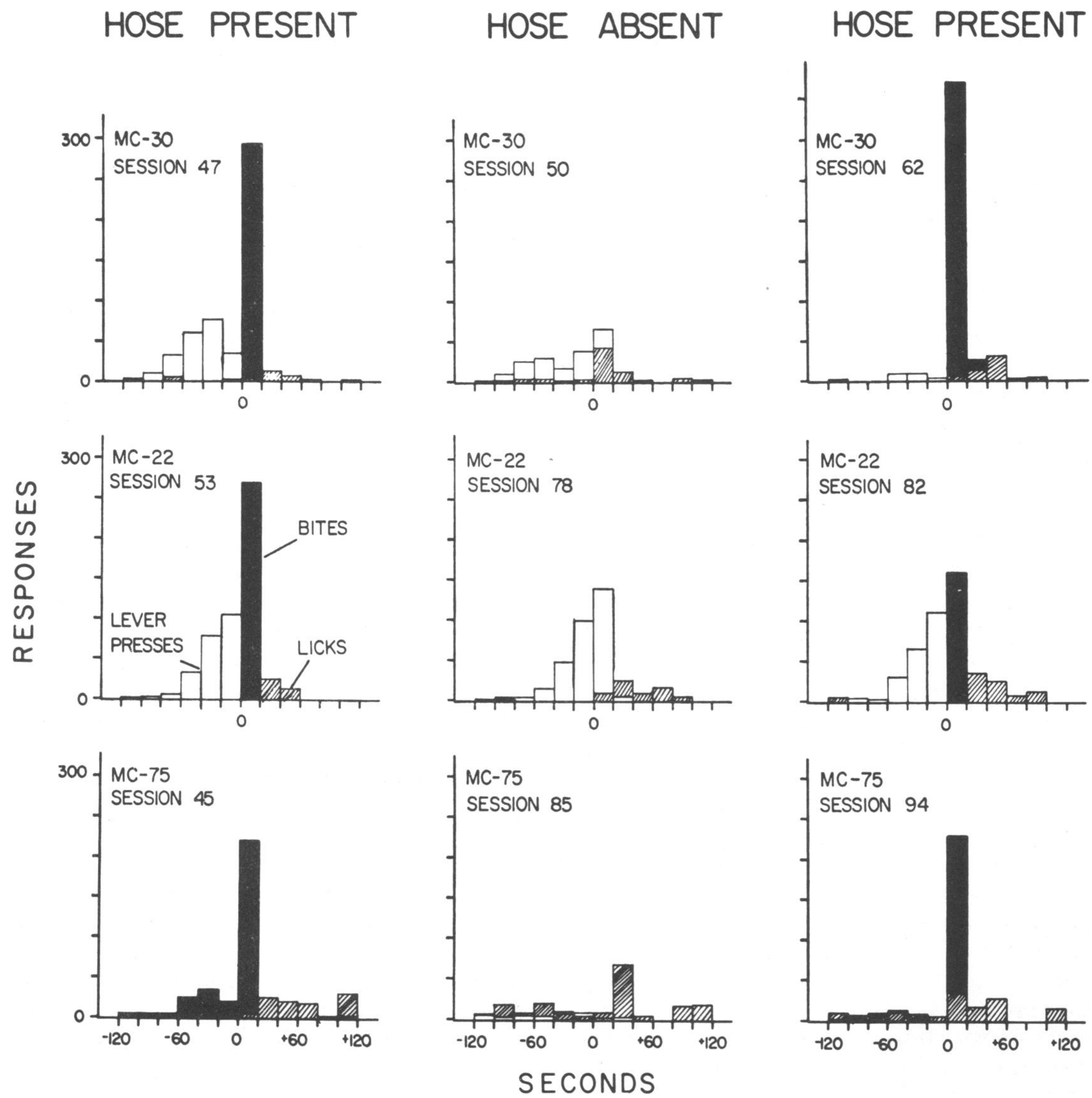


**Fig. 3.** The temporal distribution of lever pressing, hose biting, and drink-tube licking during presence and absence of the bite hose for three subjects. Shock occurred at time zero (0) sec. The upper limit of each shaded portion of each bar indicates the session response total for the specific response depicted.

body fluid osmolality, which in turn was responsible for the increased fluid intake.

In each of these studies, overall performance changes were reported in terms of total volume of water consumed in the test period. Additionally, the experiments involved imposing the independent variable at some temporal distance from the point of behavioral measurement. Handling variables and/or a change in cage stimuli might therefore have intervened between shock delivery and the measured behavior. Each report also concluded that shock delivery caused changes in intervening central states of "emotionality" and "general drive", and that these effects, in turn, affected water intake. In the present experiments, no delay in measurement existed between delivery of the noxious stimulus and the recorded episodes of fluid ingestion. The close temporal relation between shock and drinking in the present experiments reduces the need to assume a general, nonspecific, unmeasured intermediate process.

In the Levine (1965) and Moyer and Baenninger (1963) studies, measurement periods were arranged to follow rather than precede electric-shock periods. Thus, behavioral effects, seen from the present studies to be uniquely postevent tendencies, were observable. Conditional environmental stimuli preceding noxious stimuli, which can generate several behavioral sequences such an escape avoidance-type performances and response suppressions (Hutchinson, 1976; Hutchinson *et al.,* 1971; Hutchinson and Emley, 1972) were shown by the present study not to generate fluid-intake responses.

Staddon and Simmelhag (1971) showed that periodic response-independent delivery of food results in unique temporal and topographic patterns of several behaviors. Certain responses tend to occur early in the food-absent period and then decrease in time thereafter. Other reactions tend not to occur early in the food-absent period but increase in frequency up to, or until slightly before subsequent presentation of food. These later behaviors are often less frequent immediately before food presentation. Hutchinson *et al.,* (1971) Hutchinson and Emley (1972), and Hake and Campbell (1972) have shown that response-independent, fixed periodic delivery of shock also results in the occurrence of several types of behavior of unique temporal and topographic character. Biting attack occurs immediately after shock, decreasing in time thereafter. Lever pressing or chain pulling increases progressively in time toward shock, but tends to decrease immediately before shock. The several features of similarity in these two sets of experiments suggest that response-independent scheduling of both food and shock can each have similar behavior-generating influences.

The present results identify another response, having unique topographic and temporal features, which occurs in specific relation to several other events during schedules of shock delivery. Following shock, drinking occurs, and decreases in time thereafter. Where the opportunity to attack also exists, aggression occurs before drinking, and subsequent drinking is reduced.

Subjects in the present experiments were tested under several levels of water deprivation. Therefore, it might be argued that the observed temporal pattern of drinking following shock was simply the result of elevated drinking, modulated by repetitive, discriminable, aversive stimuli that produced recurrent response suppression or reduction in the later portion of the intershock interval; the response reduction was due perhaps to either a superstitious punishment or conditioned suppression process. Put more simply, it might be argued that drinking occurred immediately after shock because this was a "safe period" relative to later portions of the intershock interval. Several features of the present results restrict the suitability of this argument. Subjects consistently engaged in either lever pressing or (Subject MC-75 in Experiment IV) biting later in the intershock interval. Thus, drinking would also have to be differentially sensitive to such effects of shock. Of greater importance in judging how environmental events affected drinking was that absence of shock was related to low or zero rates of drinking, and removal of shock caused decreases in or cessation of drinking. Initiation or reinstatement of shock was followed by development or recovery of drinking. Drinking is therefore the result of a preceding shock, rather than absence of drinking being the result of a history of forthcoming shocks.

Falk (1961*a*, 1961*b*, 1971) has shown that response-independent restricted delivery of food to a food-deprived rat produces drinking early in the food-absent period. These results suggest that termination of food, a stimulus capable of serving as a positive reinforcer, produces drinking. The present experiments demonstrated that the response-independent presentation of shock, a stimulus capable of serving as a negative reinforcer, can also generate drinking. Identical positive and negative reinforcer can also produce aggression operations (Azrin, Hutchinson, and Hake, 1966; Azrin, Ulrich, Hutchinson, and Norman, 1964; Boshka, Weisman, and Thor, 1966; Hutchinson, Azrin, and Hunt, 1968; Hutchinson, Emley, and Brannan, 1970; Ulrich and Azrin, 1962).

As the present experiments demonstrate a temporal primacy of biting-attack reactions over fluid-ingestion responses following shock delivery, it will be useful for future research to discover what temporal relations exist between attack and fluid-intake responses when such occur after food delivery is terminated.

Segal's (1972) comprehensive discussion of environmental sources of response strength that contribute to later emergence of operant performances suggests the concept of "emotional induction" to subsume procedures and effects such as those reported in the present experiments. Several types of environmental conditions such as deprivation, food delivery, and shock can produce a range of performances, sometimes of nonspecific or diverse topography. In the present research, three separate performances were generated by separate features of a schedule of shock presentation, and one of these (preshock lever pressing) has been shown previously to represent but one member of a general response class (Hutchinson *et al.,* 1971). The present emphasis is to describe identifiable relations between specific conditions of the environment and features of behavior and, where possible, to point out functional identities and divergences in such relationships.

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