AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture

B. SECONDARY: Insects and Pests

2. TITLE AND SUBTITLE

Operant conditioning of licking in vampire bats, Desmodus rotundus

3. AUTHOR(S)

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4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	4p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

U.S. Dept. of Interior
Fish and Wildlife Service
Denver, Colorado 80225

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

Published in Behavior research methods and instrumentation vol.6, 1974

9. ABSTRACT

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10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAB-275	

12. DESCRIPTORS

Female Vampire Bats, Keypressing, Blood Reinforcer, Lick-response, Light Stimulus, Electric Footshock

13. PROJECT NUMBER: 931-17-190-473

14. CONTRACT NUMBER: PASA RA(ID)1-67

15. TYPE OF DOCUMENT: Research Bulletin

AID 590-1 (4-74)

Behavior Research Methods & Instrumentation
1974, Vol. 6 (5), 467-470

INSTRUMENTATION & TECHNIQUES

Operant conditioning of licking in vampire bats, *Desmodus rotundus**

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Four adult female vampire bats (*Desmodus rotundus*), weighing 28-35 g, were autoshaped to keypress to obtain 0.5-ml quantities of defibrinated cattle blood reinforcer. Keypressing required 7 g of force, and response rates were moderately low (500-600 presses/h). Because of the force requirements, the apparatus was then modified so that licking from a tube would deliver the blood reinforcer. Bats were trained on variable-ratio, fixed-ratio, variable-interval, and fixed-interval schedules. Some of the schedules produced lick response rates averaging 60/min. With conditioned suppression (light stimulus paired with brief electric footshock), bats learned within 15 sessions to completely suppress operant licking while the light was on.

Common vampire bats (*Desmodus rotundus*) are found throughout parts of Mexico and Central and South America (Villa-R., 1969). These animals live exclusively on a diet of whole blood, mainly from cattle, and are vectors for paralytic rabies and other bovine diseases (Hoare, 1965; Ornelas & Aranalde, 1964; Villa-R., 1969).

The need for development of a safe, effective, and environmentally acceptable method of controlling this species prompted questions concerning its learning and sensory capabilities. These questions then led to the development of an operant conditioning technique suitable for the vampire bat and other species of Order Chiroptera.

An operant conditioning technique for larger species of bats could not be adapted for use with vampire bats because a force of 12 g, nearly 50% of the bat's body weight, is required to press the key (pigeon key with a dipper feeder). We developed a system that uses the relatively effortless act of licking to produce high response rates with minimum fatigue.

METHOD

Subjects

Four adult female common vampire bats were obtained in Central Mexico, shipped by air to the Denver Wildlife Research Center, and placed in individual cages (17.5 x 24.1 cm) fitted with bird feeder drinking tubes and cups (Unistat No. 35543). The bats were fed approximately 15 ml defibrinated bovine blood daily. Blood was obtained from a local cattle slaughterhouse twice weekly and stored under refrigeration. Techniques for the care and handling of vampire bats are described in detail elsewhere (Wimsatt & Guerriere, 1961; Greenhall, 1965; Dickson & Green, 1970).

Apparatus

Figure 1 is a diagram of the operant-conditioning chamber (19 x 17 x 18 cm) constructed with Plexiglas sides and cover. The floor consists of 0.25-cm stainless steel rods spaced 0.05 cm apart. Alternate rods were connected to "lick-o-meter" and shock-grid circuits. The chamber was enclosed in a double-walled, sound-attenuating box and equipped with a speaker to provide white noise during each session. The program control panel for the chamber was in a separate sound-attenuating room. Responses were recorded on impulse counters and a cumulative recorder. A 7-W red houselight illuminated the chamber during training sessions. Both the houselight and a 0.5-W red cue light, mounted 2.5 cm above the drinking cup, were rheostat-controlled to gradually reduce intensity in order to dark adapt the bats before visual discrimination training.

The reinforcer consisted of a mixture of 75% defibrinated cattle blood and 25% tap water, gravity fed from an inverted 300-ml glass bottle through 3.0-mm i.d. Tygon tubing into a drinking cup 1.25 cm above the floor. The apparatus was calibrated to deliver 0.5-ml quantities of reinforcer, and the cue light flashed briefly with each delivery.

The apparatus could be programmed to deliver the reinforcer by two methods. For initial training, the drinking cup was rigidly attached to a pigeon key (Scientific Prototype K-200[2]) with a 6.35-cm length of glass tubing, and bats could earn reinforcer by pressing the drinking cup with mandible and mouth pressure. The force requirement for pressing the drinking cup and attached key was reduced from 12.0 g to 7.0 g by this arrangement. For later training, the pigeon key was electrically disconnected, and bats could earn reinforcers by licking the stainless steel licking tube, which was gravity fed with water through Tygon tubing from a second inverted 300-ml glass bottle. A sponge rubber plug was inserted into the end of the

*This research was conducted, in part, with funds provided to the U.S. Bureau of Sport Fisheries and Wildlife by the U.S. Agency for International Development under the project "Control of Vertebrate Pests: Rats, Bats, and Noxious Birds," PASA RA(ID) 1-67.

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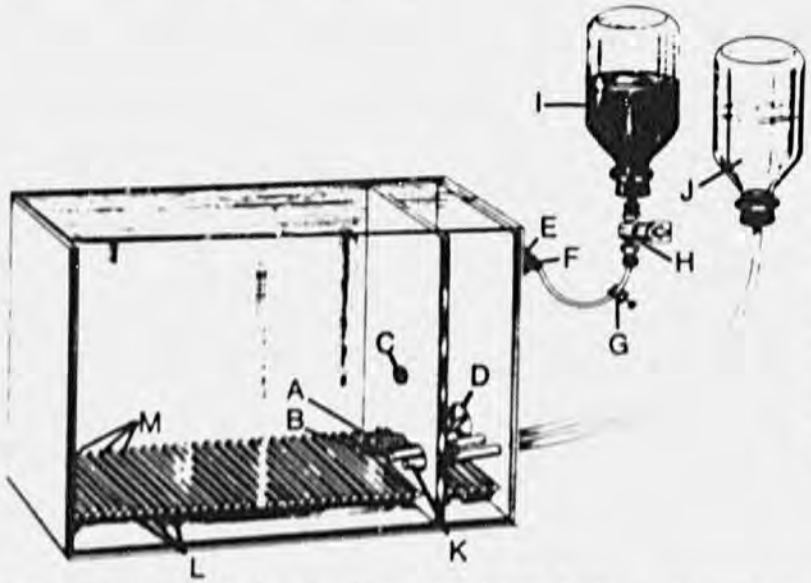

Fig. 1. Operant conditioning chamber for vampire bats: (A) drinking cup, (B) licking tube, (C) cue light, (D) pigeon key, (E) Tygon tubing looped behind back panel, (F) tube clamp connected to back panel, (G) pinch clamp for flow regulation, (H) two way Asco valve, (I) 300-ml blood solution resevoir, (J) 300-ml tap water resevoir, (K), fiber optic light tube, (L) shock-grid rods, and (M) lick-o-meter sensor rods.

licking tube to eliminate drawing and encourage licking. Each time the bat licked, the response closed a circuit between a sensor wire soldered to the drinking tube and the lick-o-meter rods in the floor, and also closed a relay for an audible feedback cue.

Procedure

The steps involved in training the bats are outlined in Table 1. Bats were first given two 16-h overnight sessions in which each keypress on the drinking cup delivered blood reinforcer (continuous reinforcement, CRF). Over the next four 16-h sessions, the bats were trained to respond on VR-10 and VR-20 schedules. Training time was then reduced to 2-h daily sessions throughout the rest of the study. The animals were allowed three daily sessions in which keypressing was reinforced on VR-20 and VR-30 schedules. The apparatus was then reprogrammed for the lick-to-drink contingency on a VR-30 schedule; the pigeon key was disconnected and the licking tube, fed with water containing 30% defibrinated blood, was introduced into the chamber. All four bats soon began steadily licking from the tube. Since they had experienced about 500 previous pairings between the red cue light and the appearance of blood in the drinking cup, no further magazine training was necessary; the bats immediately drank the blood reinforcer whenever it was delivered. Over the next five sessions, the bats were gradually trained to respond on a series of increasing variable-ratio schedules terminating with VR-100. Over these five sessions, the blood concentration in the licking tube was also gradually reduced from 30% to 0%, and the cue light above the drinking cup was dimmed to an extremely low level. No change in licking occurred when water was provided ad lib in each bat's home cage. All animals were trained on VI-100 sec; Bats 1, 2, and 4 were later trained on VR-100; Bats 1 and 4 were further trained on FR-50; finally, Bat 4 was trained on FI-120 sec. At least 12 sessions were run for each schedule.

For suppression training, a fiber-optic light tube (Fig. 1) was illuminated for 180 sec. During the last 0.5 sec of this light period, a 0.1-mA scrambled grid shock was delivered through shock-grid rods in the floor. The light tube was 6.3 mm in diam and produced a light intensity of about 1.5 cd/mm^2; it was mounted 1.25 cm from the licking tube and about 1.25 cm from the bat's right eye, for a visual angle of about 28 deg. The

Table 1
Procedural Steps for Adapting Vampire Bats to the Lick-to-Drink Contingency

Day	Session Length (H)	Reinforcement Schedule	Operant Response	Houselight Intensity	Cue Light Intensity	Blood Concentration in Licking Tube (Percent)
1	16	CRF	Keypress	High	High	–
2	16	CRF	Keypress	High	High	–
3	16	VR-10	Keypress	High	High	–
4	16	VR-10	Keypress	Medium	Medium	–
5	16	VR-20	Keypress	Medium	Medium	–
6	16	VR-20	Keypress	Medium	Medium	–
7	2	VR-20	Keypress	Low	Medium	–
8	2	VR-30	Keypress	Low	Medium	–
9	2	VR-30	Keypress	Off	Medium	–
10	2	VR-30	Lick	Off	Medium	30
11	2	VR-50	Lick	Off	Low	30
12	2	VR-50	Lick	Off	Lower	20
13	2	VR-50	Lick	Off	Lowest	10
14	2	VR-100	Lick	Off	Lowest	0

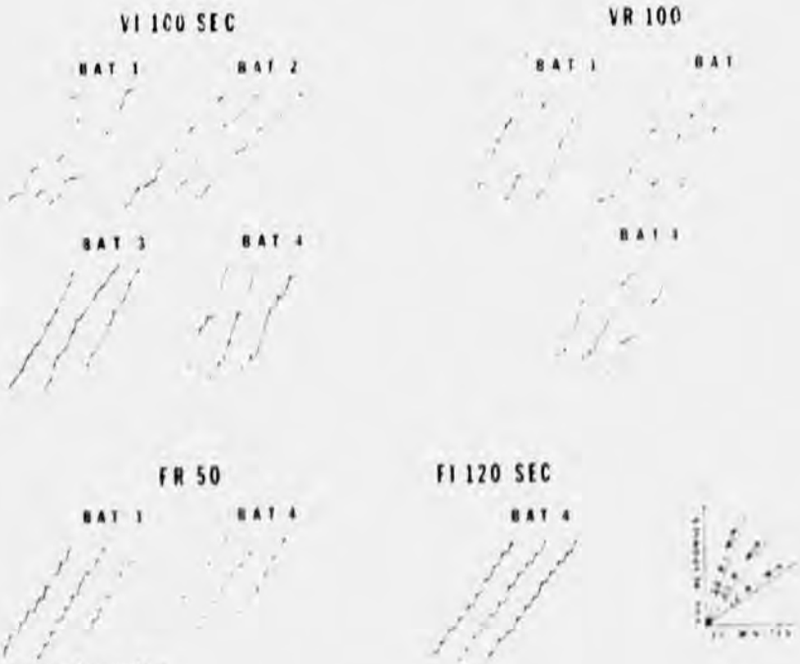

Fig. 2. Cumulative licking response records for four vampire bats during single sessions with VI 100-sec, VR 100, FR 50, and FI 120-sec schedules of reinforcement. Downward pen deflections are reinforcer deliveries.

conditioned suppression paradigm was superimposed on the VI 100-sec schedule for Bats 1 and 4; reliable suppression was produced within 15 sessions.

RESULTS

Although the bats readily learned to press the modified pigeon key, the effort involved was considerable (7 g is over a quarter of a vampire bat's body weight). Maximum operant rates under these conditions were 500-600 keypresses/h, which were judged to be too low for the assessment of brief stimuli. Substitution of licking for keypressing greatly increased the number of responses. During the first sessions with the licking apparatus, two of the bats initially appeared to water-load on the licking tube and to sometimes continue licking through reinforcements. However, the small sponge rubber insert in the licking tube and the feedback relay click for each lick tended to minimize these effects, and steady operant behavior was established for all bats by about the sixth session of the lick-to-drink contingency.

Cumulative response records for the four schedules of reinforcement are shown in Fig. 2. On the VI 100-sec schedule, Bats 1, 3, and 4 averaged 40 responses/min; Bat 2 averaged 20/min. Bats 1, 2, and 4 showed about the same rates on the VR 100 as on the VI 100-sec schedule. With the FR 50 schedule, Bats 1 and 4 increased their rates to about 60 responses/min and showed consistent postreinforcement pausing. Bat 4 on the FI 120-sec schedule showed a slight "scalloping" characteristic of fixed-interval schedules; initial response rates averaged 25/min, and terminal rates averaged almost 60/min.

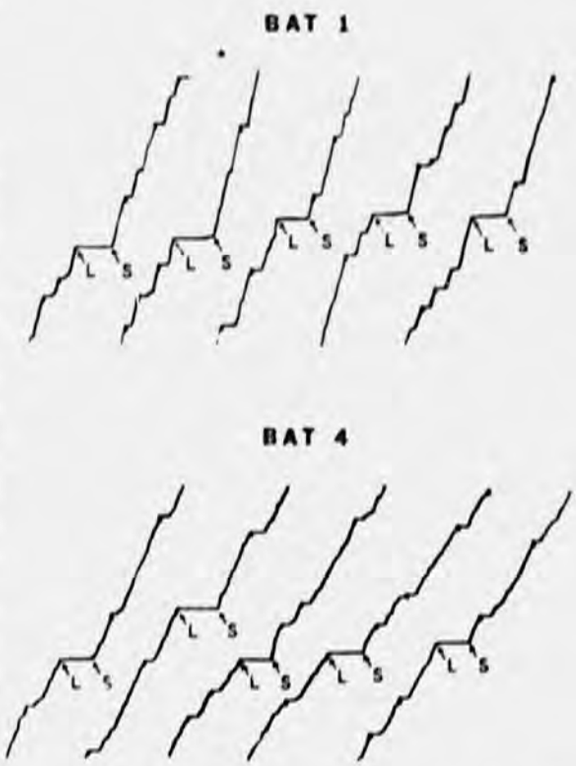

Fig. 3. Cumulative licking response records and suppression behavior of two vampire bats for a single session on a VI 100-sec reinforcement schedule with a conditioned suppression paradigm (180-sec light stimulus paired with a scrambled-grid footshock the last 0.5 sec). (L) represents light onset and (S) represents shock.

Suppression behavior of Bats 1 and 4 is shown in Fig. 3. Since the animals were licking for blood reinforcer in total darkness, there was an initial suppression response to the stimulus light early in training, but the pause lasted only 20-30 sec. After repeated light-shock pairings, each bat showed complete suppression during the entire 180-sec light period and resumed licking within 2-3 sec after the shock stopped.

DISCUSSION

Beecher (1971) described a successful technique for operant conditioning of large bats (*Phyllostomus hastatus*, weighing 60-75 g) which requires a 12-g force for the keypress response; this is too much effort for vampire bats and other Chiroptera that weigh less than 50 g. With vampire bats, direct keypressing has the further disadvantage that the key soon becomes coated with blood. The licking response, although somewhat unnatural for the vampire bat, is relatively effortless and provides a steady, high-rate response baseline.

Our licking-response apparatus is simple and can be modified to deliver solid food, or to deliver liquid reinforcers through a syringe pump. Introducing a perching bar above the licking tube and drinking cup enables the apparatus to also accommodate bats that feed while hanging upside down; vampire bats in their home cages readily drink blood in this position.

In our tests, no manual shaping of either the keypress or licking response was necessary, and bats trained to lick in single 2-h daily sessions established reliable operant behavior in 2 weeks, responding with predictable baselines to VR, VI, FR, and FI reinforcement schedules. The response baselines were also sensitive to conditioned suppression; trained bats stopped licking almost immediately when the stimulus light was presented and rapidly resumed licking at their normals rates after the light and shock stopped. We used bats trained in this way in preliminary tests to determine absolute visual sensitivity thresholds by the conditioned suppression technique first described by Hendricks (1966). Responses to other kinds of stimuli can also be evaluated, e.g., the relative importance of the various systems used in prey location, obstacle avoidance, and general orientation.

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(Received for publication June 4, 1974;
(revision received July 24, 1974.)

NOTES

1. Lustar Products Company, Springfield, New Jersey 07081. Reference to trade names does not imply Government endorsement of commerical products.

2. Scientific Prototype Mfg. Corp., 615 West 131st Street, New York, New York 10027.