Physiology and Behavior, Vol. 8, pp. 565–568. Brain Research Publications Inc., 1972. Printed in Great Britain.

BRIEF COMMUNICATION

The Reinforcing Effect of Electrical Stimulation of the Tongue in Thirsty Rats

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(Received 4 June 1971)

SLANGEN, J. L. AND J. A. W. M. WEIJNEN. *The reinforcing effect of electrical stimulation of the tongue in thirsty rats.* PHYSIOL. BEHAV. **8** (3) 565–568, 1972.—Thirsty rats repeatedly closed the electric circuit of a drinkometer with their tongue in the absence of water. The hypothesis that electrical stimulation of the tongue has reinforcing properties was tested. The results indicate that persistent licking by a thirsty rat is dependent on a current as low as 1 μA.

Drinkometer Tongue stimulation Licking for current

IT HAS BEEN found that water deprived rats not only lick for water but also for air or nitrogen [2, 3]. Evidently, the air or nitrogen puff that immediately follows the licking response can have reinforcing properties for a thirsty animal. Mendelson and Chillag [5] hypothesized that the cooling of the tongue by the airstream is sensed by cold receptors.

We observed that thirsty rats displayed high rates of licking behavior when a lick resulted in the contact with a stainless steel ball at room temperature and in some current flow through the animal accompanied by the closing of a drinkometer circuit. The present report describes our first observations and an experiment performed to determine whether the licking behavior of water deprived rats is dependent on current flow through the tongue of the licking animal.

METHOD

The animals were Wistar rats of an inbred lab colony weighing 180–230 g at the beginning of the experiment. The apparatus consisted of a Skinnerbox containing an electrically operated water-dipper, a house-light, a stimulus light and a photocell with accompanying light source. Attached to the ceiling was a lucite tube at the end of which a lucite disc (18 mm dia.) enclosed a stainless steel ball (Fig. 1). The ball was connected to the input lead (−12 V) of a BRS drinkometer (BRS Electronics DO-101). The ground lead (oV) was connected to the grid floor of the box. When an animal entered a small compartment attached to one of the steel walls of the Skinnerbox, a photocell was operated and the output of this device was used to activate a clock, which in turn activated the dipper for 3.5 sec (Fig. 1). Licks from the cup could be detected by means of a second BRS drinkometer. Entering the compartment will be called R1 and the contact with the stainless steel ball will be called R2. Experiments started when the subjects were 48 hr water deprived. On

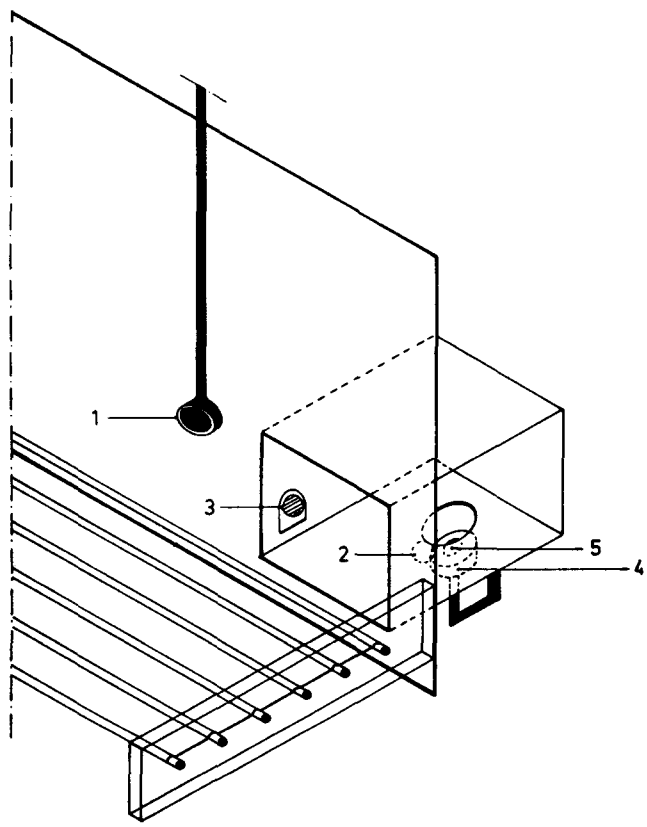

FIG. 1. Schematic drawing of part of the Skinnerbox containing the small drink compartment. 1. stainless steel ball; 2. light source; 3. photocell; 4. dipper; 5. stainless steel disc (second drinkometer).

experimental days subjects received water on a continuous reinforcement schedule (CRF) in sessions lasting 20 min or 100 S^R's, whichever came first. However, half an hour after the end of a session each subject received an additional amount of water so that the total daily intake was 12 cc.

Preliminary Observations

After 11 days of training on the CRF schedule, four male rats were given three days of extinction sessions (lasting 30 min each). During extinction all four animals started to lick frequently at the stainless steel ball. The median number of R2 responses emitted by the 4 animals was 5292, 770, 2368, 1887. When the CRF schedule was reinstated for 8 days, the frequency of R2 immediately dropped to the preextinction level of less than 10 responses per session. In a second series of 7 extinction sessions the rate of R1 decreased regularly over sessions while the R2 rate remained very high for three animals (Fig. 2). Occasionally we observed that, although R2 was emitted, the response was not counted. An oscilloscope and a Grass polygraph were used in order to detect all R2's and to get a permanent record of current values. Both devices recorded voltage changes across a 1KΩ resistor in series with the rat.

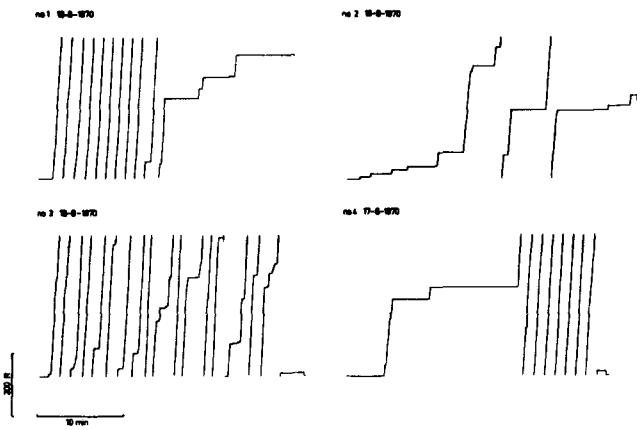

FIG. 2. Cumulative records obtained from 4 animals showing high rates of ball licking during an extinction session. (Signs of non-responding are not reliable. See text).

Repeating the first observations with four male animals it was found that during their first extinction session which lasted 30 min, these animals emitted 1540, 1241, 2003 and 2902 R2's. The current during contact was 20–50, 40–60, 10–15 and 15–20 μA respectively. Occasionally in subsequent extinction sessions higher or lower current values were observed. The drinkometer became unreliable at lower current values. When the output of the Grass pen driver was connected to a Schmitt trigger which in turn operated a read relay, the number of responses that were counted and recorded reliably increased. Even under these circumstances one fifth of the emitted responses were not recorded except by the polygraph. When, after improvement of the recording technique, daily extinction sessions were continued for at least 14 days, no decrease in the high licking rates was observed.

EXPERIMENT 1

Our initial results suggested, that water deprived animals will frequently emit a response that seemingly has no other effect than to cause an ion flow through the animal. The purpose of this experiment therefore was to find out whether the high rate of R2 performance by thirsty animals was dependent on current flow.

Procedure

Five male and three female naive animals were deprived and conditioned on the same schedule as described for the exploratory experiments.

Having established a CRF baseline for R1 we changed the situation in such a way that only R2 was followed by S^R. This procedure ensured that all animals in this experiment had the same amount of training in emitting R2. There were 8 daily conditioning sessions in which R2 produced S^R. They lasted 30 min each or 100 S^R's, whichever came first. CRF conditioning sessions were followed by 4–6 extinction sessions of 30 min duration. For Group 1 animals the external resistance in the DO circuit was increased with a 21 MΩ resistor to reach a current level of 1 μA or less (short circuit value). For Group 2 animals there was no external resistance added. After these extinction sessions the animals of Group 1 and 2 were reconditioned in one session (CRF schedule) and put on an extinction schedule for three days. During this second series of extinction sessions no external resistance was added in the circuit for the Group 1 animals whereas for the animals of Group 2 21 MΩ resistance was added.

RESULTS

During CRF the baseline behavior of the animals in both groups was the same. As expected, all animals showed during extinction a regular decrease in R1 responding (see Table 1). Three animals in Group 1 showed convincing extinction of R2 responding. The number of R2 responses made by rat M8 was reduced when the external resistance was increased to 24 MΩ (0.4 μA); in two daily sessions this rat produced a total of only 25 and 32 R2 responses. In Group 2 two animals showed a high rate of R2 responding. A high rate of licking was observed in the other two animals from the fifth day on. Rat M4 started to lick at a rate of six responses per sec when the resistance in the circuit was increased so that the current through the rat was held below 10 μA. When the conditions were reversed for the two groups, R2 responding increased 9 to 75 fold for group 1 and returned to pre-extinction level for group 2. An illustration of how rate of licking is dependent on a threshold current, can be seen in fig. 3. None of the animals licked when they were satiated. Occasionally, when animals were tested in sessions lasting more than an hour, no sign of true extinction or satiation was seen.

DISCUSSION

The fact that animals continued to lick a stainless steel ball for 30 or 40 min at very high rates, led us to hypothesize that the electrical stimulation of the tongue which occurred as a consequence of closing the drinkometer, was the event responsible for the continued performance. We investigated whether the persistent licking behavior was dependent on the

TABLE 1

Group 1 Animals	R1	R2	μA	Group 2 Animals	R1	R2	μA
M2	108	769	0.8	M4	127	1200	10–50
	40	223	1		63	520	10–60
	32	137	1		58	207	10–40
	40	78	1		13	52	10–50
					7	3001	3–10
					10	6166	1– 8
M7	87	364	0.8	V14	82	229	4–45
	71	365	1		79	755	6–25
	53	89	1		58	340	4–32
	34	84	1		50	61	2–20
					31	3252	20–60
					28	4170	16–50
M8	53	670	0.8–1	V13	59	4511	6–62
	61	882	0.8–1		25	4605	6–64
	52	1736	1		22	6717	6–60
	15	1074	1		8	5769	10–60
					11	5938	10–70
					8	1066	12–40
V11	130	426	0,8	M5	74	2997	2–62
	77	230	0.7–1		23	2840	2–18
	56	167	0.8–1		40	3095	2–20
	51	87	1		23	2753	2–26
					21	7200	1–25

Current range during contact closure and total number of R1 and R2 responses of Group 1 and 2 animals in consecutive extinction sessions. For Group 1 animals the circuit resistance was increased with 21 MΩ

amount of current flow through the rat when the circuit was closed. The results show that thirsty rats will perform a lick response at the rate of 5–7 R/sec whenever performance produces a current flow of about 1 μA or more through the tongue. Responding ceases when the current is less than 0.5 μA. This threshold of 1 μA is extremely low compared for example with the thresholds usually encountered in self-stimulation experiments or in experiments in which behavior is elicited by means of electrical stimulation of the brain [1, 4, 6]. On the other hand, a value of 1 μA or less (taking into account that part of this current will leak away along the surface of the tissue without affecting sensory neurons) seems to be within the appropriate physiological range for stimulating sensory neurons. It is evident that with dehydrated rats the use of contact sensing devices such as drinkometer circuits can lead to false conclusions when devices use currents higher than 0.5 μA. In fact, it seems that every possible source of voltage difference in the environment of a thirsty rat may be used by the animal as reinforcing stimulus source as long as: (1) water is not available; (2) the animal is able to close the circuit with its tongue; and, (3) a current of more than 0.5 μA can be sustained during circuit closure.

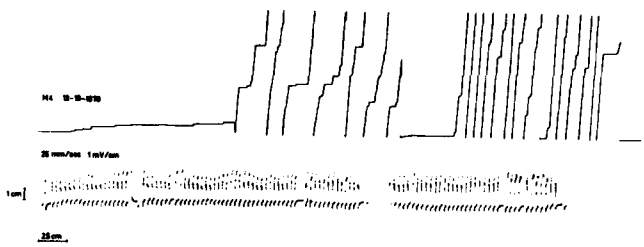

FIG. 3. Cumulative record of R2 responses produced by rat M4 in an extinction session lasting 1.5 hr. During the first 30 min of this session 21 MΩ were connected in series with the rat, causing the current flow through the rat during a lick contact to drop below threshold level. When the extra resistance was removed, responding increased gradually until finally the response rate was 5 à 7 R/sec, as can be seen in the sample of the Grass record taken from the last part of the session. Note that the current level is between 1 and 2 μA.

The technical assistance of C. W. A. Broekman is gratefully acknowledged. Dr. J. Cruce was very helpful in improving the style of the manuscript.

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