Reinforcement of intracranial self-stimulation by licking[1,2]

SOLON B. HOLSTEIN AND ALAN G. HUNDT[3,4]
UNIVERSITY OF MISSOURI

Abstract

Parameters which made licking more probable than intracranial self-stimulation (ICSS) were used. Under these conditions, ICSS served as an instrumental response and licking as the reinforcing response. When licking was made contingent on ICSS, ICSS was greatly increased relative to its base duration and frequency.

Problem

Premack has suggested that for any pair of responses, the more probable response will reinforce the less probable one. Diverse data has supported this generalization (Premack, 1962, 1963a, 1963b).

Can Premack's generalization be extended to ICSS? Given a response, licking, that is more probable than ICSS, will licking reinforce ICSS?

Method

Three Long Evans male rats were implanted with bipolar electrodes. To determine if anatomical site would circumscribe the experimental results, the site selected was different for each rat. The electrode tips were confirmed in post-experimental histologies to be in the midbrain tegmentum, preoptic region and the median forebrain bundle of the posterior hypothalamus. Postoperatively the S's were placed on a 10 gm daily ration of lab chow and ad lib water for the duration of the experiment.

In order to estimate the probability of lick and ICSS, stable operant levels were separately established for each event in daily 15-min. sessions. In these sessions each rat was introduced into a standard experimental chamber which had provision in one wall for a small bar and a retractable lickometer. Whenever and for as long as the animal pressed the bar, the output of a stimulator circuit, programmed in conjunction with the bar, provided a constant current—100 cps sine wave stimulus. In one of the twice daily 15-min. sessions only the lickometer was present and in the other only the ICSS bar. The order of ICSS and lick sessions alternated from day to day. A current value providing a stable, moderate total duration of ICSS yet lower than total licking duration maintained by 25% sucrose solution was selected for each rat. For all three animals, in either presentation order, the total duration of licking always surpassed that of ICSS. Table 1 summarizes current parameters and response data.

To obtain a second pre-reinforcement measure, the tube and the ICSS bar were made concurrently available. Two factors advised this step. (a) Pairing the tube and the ICSS bar may possibly disturb the ordinal relation between the individual response probabilities. Therefore it is desirable to have some measure of the possible effect of pairing as such (Brownstein, 1962). (b) We have found, along with others (Hodos & Valenstein, 1962), that bar-press duration per se may be an inadequate measure of ICSS reinforcement value; at some intensities a "recoil" response occurs after each bar press but is not measured by a clock simply registering bar-press duration. However, the recoil topography, if present, would compete with licking in the situation where both were concurrently available and would reveal itself by a reduction in the duration of licking. The animals were given daily 15-min. sessions with both tube and ICSS bar freely available until the behavior in each was stable. Table 1 shows that the ordinal relationship between the estimated probabilities of licking and ICSS were maintained relative to the alternation test session procedure and that in all cases licking duration exceeded ICSS by a considerable margin.

Conditioning began after stable performance in the concurrent test condition had been established. To receive the retracted drinking tube for some predetermined period of contingent time (CT), the animal had to press the continuously present ICSS bar for some predetermined FR. When all animals had stabilized under conditioning parameters they were returned to the concurrent test condition to determine whether the initial relationship between the likelihood of licking and ICSS could be recovered.

Finally two controls were run. While maintaining the same parameters the first control sought to determine if ICSS could be made to reinforce licking. If this happened then the argument used to explain the reinforcement of ICSS by licking—that the probability of licking is relatively greater than that of ICSS—would be refuted. To provide an exacting test of this possibility, which would not be circumscribed by the reported difficulty of generating high fixed ratio responding with ICSS (Sidman et al, 1955), a minimal instrumental requirement of one lick was used.

Table 1. Chronological Summary of Conditions: Stable Durations of Licking and ICSS Responding.

Subject	S-1		S-2		S-3	
Electrode Placement	Midbrain Tegmentum		Preoptic Region		Median Fore-Brain Bundle	
Current	16 μa		19 μa		37 μa	
ICSS or Lick	ICSS	Lick	ICSS	Lick	ICSS	Lick
Alternating Current	120.4	416.4	320.4	528.3	210.7	670.0
Concurrent Operant	103.3	387.6	268.6	486.8	245.8	659.5
Conditioning (ICS ⊃ Lick) FR5-CT8*	194.8	376.7	409.1	321.4	427.0	109.6
Recovery	110.6	406.5	259.3	457.2	244.2	630.1
Reversed Control (Lick ⊃ ICS) FR1-CT10	97.8	393.4	241.2	452.7	250.9	604.9

*Except FR10-CT3 for S-3

To determine if licking reinforced ICSS rather than bar pressing—with ICSS an incidental factor—was the objective of a second control. A comparison of the effect of licking upon bar pressing in one case, and licking upon bar pressing-brain stimulation in the other case should answer this question. If brain stimulation is incidental, the duration of reinforced bar pressing should be the same as reinforced bar pressing-brain stimulation. To test this possibility two additional Long Evans rats were implanted with electrodes aimed at the lateral hypothalamus, and trained in the same manner as described above. Following completion of the base level measurements, one animal was trained to bar press for licking, extinguished, and then trained to bar press-brain stimulation for licking; the other animal received identical training in the reverse order.

Results

As indicated in Table 1, the lick contingency greatly increased the duration of ICSS, for all animals, relative to either the alternating single or the concurrent operant level condition. The reinforcement of ICSS was also evident from the pattern of responding shown in the Esterline-Angus records; licking always followed the completion of the FR requirement of ICSS. In contrast, when in the first control the less probable response, ICSS, was contingent upon a more probable response, lick, there was neither an increment in lick duration nor the alternation pattern found in reinforcement. Rather the duration and irregular patterning of licking and ICSS were comparable to baseline conditions.

Finally the main results for the second control, which examined the role of brain stimulation in the reinforcement of ICSS, is summarized in Fig. 1. When lick reinforced bar pressing-brain stimulation, the total duration of responding was consistently higher than when lick reinforced simply bar pressing. Thus, the effect of brain stimulation was decidedly relevant. Significantly, results for more traditional cases concur with the above—the greater the pre-reinforcement level of the instrumental response, the greater the reinforcement level produced by one and the same reinforcer (Schaeffer, in press).

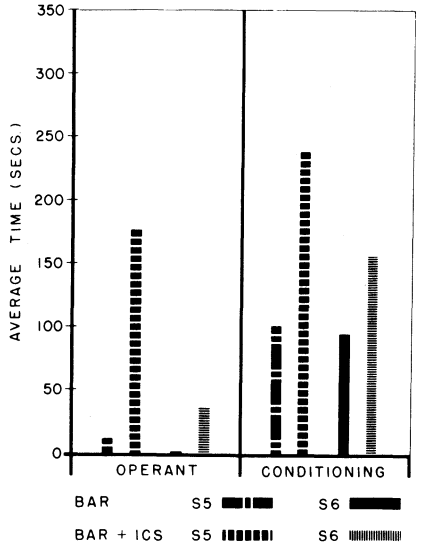

Fig. 1. Total duration of responding during operant level and conditioning procedures for bar pressing compared with ICSS-bar pressing.

Discussion

Behavioral theories traditionally view reinforcement as an absolute property of certain stimuli (Hull, 1943; Skinner, 1938). Recent neurological theories (e.g., Olds, 1962; Miller, 1963), which identify the property of reinforcement with the function of certain neurological loci, are analogues of the traditional theories. Being more specific about the nature of the intervening reinforcement process, these neurological extensions attain greater plausibility than the parent behavior theories but they, too, consistently rest upon an absolutistic framework. Reinforcement depends upon an absolute and "transituational" property of certain stimuli.

As early as 1958, and in later reports (Premack, 1962; 1963a; 1963b), however, sufficient behavioral data appeared to challenge this traditional view and to suggest a relative theory of reinforcement. The results of the present experiment, the reinforcement of ICSS by licking, using diverse anatomical loci, support these behavioral data and affirm the assumption that behavior generated by brain stimulation is comparable to that generated by activity wheels, food or other common stimuli. In contrast, the present data cannot support the claim that there are reinforcement "centers" which have, absolutely, the property of facilitating all response events.

A framework able to explain reinforcement as a relative relationship between response probabilities obviates the necessity of seeking specific neural centers as absolute reinforcement mechanisms. The present study demonstrates the applicability of this relativistic view of reinforcement, moreover, it does so by extending a behavioral generalization originally developed in conjunction with typical stimuli and responses to ICSS.

References

Brownstein, A. Predicting instrumental performance from the independent rates of contingent responses in a choice situation. *J. exp. Psychol.*, 1962, 63, 29-31.

Hodos, W., & Valenstein, E. S. An evaluation of response rate as a measure of rewarding intracranial stimulation. *J. comp. physiol. Psychol.*, 1962, 55, 80-84.

Hull, C. L. *Principles of behavior.* New York: Appleton-Century, 1943.

Miller, N. E. Some reflection on law of effect produce a new alternative to drive reduction. In M. R. Jones (Ed.), *Nebraska Symposium.* Lincoln: University of Nebraska Press, 1963. Pp. 65-112.

Olds, J. Hypothalamic substrates of reward. *Physiol. Rev.*, 1962, 43, 554-604.

Premack, D. Toward empirical behavior laws. I: Positive reinforcement. *Psychol. Rev.*, 1959, 66, 219-233.

Premack, D. Reversibility of the reinforcement relation. *Science*, 1962, 136, 255-257.

Premack, D. Rate differential reinforcement in monkey manipulation. *J. exp. Anal. Behav.*, 1963a, 6, 81-89.

Premack, D. Prediction of the comparative reinforcement values of running and drinking. *Science*, 1963b, 139, 1062-1063.

Schaeffer, R. Contributions of the operant level of the instrumental response to the reinforcement relation. *J. exp. Psychol.*, in press.

Sidman, M., Brady, J. V., Boren, J. J., & Conrad, D. G. Reward schedules and behaviors maintained by intracranial self-stimulation. *Science*, 1955, 122, 830-831.

Skinner, B. F. *The behavior of organisms.* New York: Appleton-Century, 1938.

Notes

1. The research was aided by grants NSF GB 1379 and USPHS MH 05798, David Premack, principal investigator whom we thank for his contribution to all phases of the research.

2. This research was presented in part at the Psychonomic Society, 1964.

3. The order of authorship was determined by coin flip.

4. It was completed while Solon B. Holstein was a NASA predoctoral trainee. The manuscript was prepared while Alan G. Hundt was a postdoctoral NIMH fellow at the University of Pennsylvania.