

other reinforcements, such as that produced by eating. As a general explanation, however, this does not seem to be the case. Two of our eaters (not stimulus-bound drinkers), when deprived of water for 48 hours and presented with water instead of food by the bar in a stimulation condition, never pressed once while they were drinking as they might have been expected to do if summation of two types of reinforcement, in this instance water and subthreshold intracranial stimulation, could account for the results of this study.

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11. Supported in part by NIH predoctoral fellowship, 1-F1-MH-38, 971-01A1 (J.A.F.C.) and by an NIH biomedical science support grant to New York University. We wish to express our thanks to Natalie D'Allesio for her assistance in running rat F.

5 December 1967

8 MARCH 1968

Modification of Motivated Behavior Elicited by Electrical Stimulation of the Hypothalamus

Abstract. Previous reports demonstrated that hypothalamic stimulation may elicit either eating, drinking, or gnawing and emphasized both the specificity of the neural circuits mediating these behaviors and the similarity to behavior during natural-drive states such as hunger and thirst. We find that, after a period of very consistent elicitation of one of these behaviors, the animal may exhibit an equally consistent alternate behavior. A learning component is implicated in the association of hypothalamic stimulation with a particular behavior pattern.

Hypothalamic stimulation in the rat may elicit behaviors such as eating, drinking, and gnawing (1, 2); previous reports have emphasized both specificity of the neural structures activated and similarity of the behavior to that occurring during natural-drive states. As satiated animals exhibit the behavior only during the period of stimulation, the term "stimulus-bound" behavior has been applied. From the fact that animals that exhibit such behavior will perform some learned task (instrumental behavior) to obtain a relevant goal, it has been concluded that the stimulation does not trigger a stereotyped motor act, but activates a motivational state such as hunger or thirst.

We studied the development of "stimulus-bound" behavior and the possibility of modifying the elicited behavior in the absence of any change in stimulation site or stimulation parameters. Our results indicate that there is a learning component involved in the association of hypothalamic stimulation with such behavior as eating, drinking, or gnawing. Hence, we question those theoretical positions based on the conclusion that electrical (and perhaps chemical) stimulation activates fixed neural circuits mediating natural-drive states.

Bipolar electrodes (3) were implanted in the lateral hypothalamus of mature Holtzman albino rats of both sexes. With the dorsal surface of the skull level between bregma and lambda, the electrodes were positioned 2.50 to 3.50 mm posterior to bregma, 1.25 to 1.50 mm lateral, and 8.25 to 8.50 mm below the top of the skull (4). Animals were stimulated with either 30-second trains of 60-cycle sine waves or biphasic rectangular pulses (frequency, 100 pulses per second; pulse duration, 0.2 msec). The stimulus parameters used with each animal are provided in Table 1. All stimulation was programmed by automatic equipment and was not delivered under the experimenter's control.

After surgery but before any stimula-

tion, the animals were placed individually in Plexiglas cages which served as living quarters and testing chambers. Light in the room was on from 7:00 a.m. to 7:00 p.m. each day. The cages contained three goal objects: pellets (Purina Lab Chow), a water bottle with a metal drinking tube, and a pine wedge mounted either on the wire-mesh floor or one of the walls. During preliminary screening to determine an appropriate stimulus intensity, animals were stimulated for a 30-second period followed by a 60-second interstimulus interval. The intensity was adjusted until the stimulus elicited a forward-moving "searching" behavior. If, after a period of time, the animal did not exhibit either eating, drinking, or gnawing in response to stimulation, the intensity was raised or lowered to what appeared to be a more promising level. If no specific behavior pattern emerged, the animal was stimulated throughout the night for 30 seconds every 5 minutes (night schedule). If no "stimulus-bound" behavior was evident, the sequence was repeated during at least one additional night before the animal was rejected. With this procedure, approximately 25 percent of the animals exhibited "stimulus-bound" eating, drinking, or gnawing on the pine wedges.

The animals that exhibited "stimulus-bound" behavior were then given a series of three standard tests (30 minutes in duration, with twenty 30-second stimulation periods, each separated by a 60-second interstimulus period). There was a minimum of 30 minutes between each test. During these tests, the three goal objects were present. After this first series of tests, the goal object to which the rat oriented was removed, and the animal was left overnight with the other two goal objects and stimulated on the night schedule. If, for example, the rat exhibited "stimulus-bound" drinking during the first series of tests, the water bottle was removed during the night, and only the wood and food pellets were left in the cage. The stimulus pa-

Table 1. Eating (E), drinking (D), and gnawing (G) behavior elicited during hypothalamic stimulation. Each test had 20 stimulation periods. Maximum score for any one behavior is 20, but the animal could exhibit different behaviors during each period. The dash (—) in the second series of tests indicates which goal object had been removed. RP, rectangular pulses; SW, sine wave. All animals except 80S were males.

Animal	Behav- ior	Test series					Compe- tition	Stimulus parameters (μ a)
		First series			Second series			
		1	2	3	1	2		
60S	E	0	0	0	15	17	11	RP, 80
	D	20	20	20	—	—	14	RP, 80
	G	0	0	0	0	0	0	RP, 80
61S	E	0	0	0	20	20	15	RP, 120
	D	20	20	20	—	—	12	RP, 120
	G	0	0	0	0	0	0	RP, 120
63S	E	0	0	0	0	0	0	RP, 500
	D	0	0	0	20	20	12	RP, 500
	G	20	20	20	—	—	8	RP, 500
74S	E	0	0	0	20	20	12	SW, 20
	D	20	20	20	—	—	13	SW, 20
	G	0	0	0	0	0	0	SW, 20
80S	E	19	16	12	—	—	10	RP, 120
	D	1	5	8	19	16	10	RP, 120
	G	0	0	0	2	2	6	RP, 120
89S	E	0	0	0	18	20	16	SW, 24
	D	19	19	20	—	—	4	SW, 24
	G	0	0	0	0	0	0	SW, 24

parameters remained unchanged. If the animal did not exhibit a new "stimulus-bound" behavior, it was stimulated additionally on consecutive nights. In most cases, however, one night was sufficient time for a new behavior to emerge, although for animals 60S and 89S several nights were necessary. In general, the earlier the onset of the first behavior during the preliminary stimulation sessions and the more consistently this behavior was displayed, the sooner the animal switched to a second behavior pattern when the first goal object was removed. Animals were then given two additional standard tests with the initial goal object still absent. Finally, the animals were given a competition test with all three goal objects present. Prior to all tests, animals were provided with an opportunity to satiate themselves on food and water.

Eating and drinking were scored only when there was clear evidence of consuming the food or water (Table 1). The food pellets were held with the front paws, and pieces were bitten off; the drinking tube was lapped, and the animal could be observed ingesting the water. Gnawing consisted of biting off pieces of wood from the wedge. In most cases, the animal began the "stimulus-bound" behavior within 1 to 2 seconds after the onset of the stimulus and stopped abruptly after its termination. The duration of the "stimulus-bound" behavior was variable. In a number of instances, the animal ate, drank, or

gnawed for the entire 30-second stimulation period, and in a few cases the behavior was observed for only a 5-second period. Only in rare instances was any scoreable behavior observed during the interstimulus period. Table 1 illustrates that the "stimulus-bound" behavior during the first series of tests was exhibited consistently with almost every stimulus presentation. The second series was administered after the animal spent a variable amount of time receiving stimulation without the first goal object present. In most cases the second "stimulus-bound" behavior was exhibited as consistently as the first behavior (Table 1). During the competition test, when all three goal objects were present, approximately equal amounts of the two "stimulus-bound" behavior patterns were displayed in most instances, although the second behavior—eating—dominated the behavior of 89S during the competition test. In the case of 80S (an animal that exhibited two behaviors initially), a third behavior pattern—gnawing—was observed during the second series of tests and the competition test. This animal had been placed on the night schedule for two consecutive nights with only wood and water present. In addition to eating, drinking, and gnawing, other behavior was observed to be elicited by the stimulation in some animals; for example, 80S frequently positioned itself in one part of the cage, and with the onset of stimulation a specific path was traversed

on the way to the drinking bottle.

There were no cases of "stimulus-bound" behavior which could not be switched to another behavior with the stimulus parameters held constant. We cannot be certain that such a case might not exist, but, in addition to the data in Table 1, there were a number of instances in which there were "spontaneous" switches from one "stimulus-bound" behavior to another. For example, an animal that might exhibit "stimulus-bound" gnawing approximately 50 percent of the time might switch to drinking with approximately the same consistency. We regard these cases of "spontaneous" switching as additional evidence of the lack of specificity of the behavior evoked by electrical stimulation. This conclusion is also supported by animal 80S, as well as others that did not complete the test series, which exhibited more than one behavior from the beginning of stimulation.

In stressing the lack of specificity between a given behavior pattern and lateral hypothalamic stimulation, we are not advancing a position of neural equipotentiality. We were not able to evoke either eating, drinking, or gnawing from a number of lateral hypothalamic sites. Furthermore, in several animals in which electrodes were placed in somewhat different lateral hypothalamic sites on the left and right side, the animal exhibited "stimulus-bound" behavior only when stimulated on one of the sides.

It might be argued that all the animals used in our experiment were special cases in which stimulation activated simultaneously the neural circuits mediating two motivational systems. We disagree for several reasons. We did not select the animals, and we studied all that exhibited any "stimulus-bound" behavior. Only one of the animals exhibited more than one behavior pattern before our effort to modify their responses. Of the animals exhibiting only one behavior initially, those that displayed the most vigorous pattern (judged by the brief latency, long duration during stimulation, and great consistency) required the least amount of training for a second pattern to emerge.

As far as we could determine, most investigators of "stimulus-bound" behavior focused on a specific behavior. As a result, the animals received either or both special training or limited opportunity to display different patterns. Those few instances in which an animal was given a brief "competitive" test

with another goal object present usually followed an extensive amount of opportunity to display the initial behavior pattern. We found that the more opportunity an animal has to exhibit a specific "stimulus-bound" behavior, the longer it may take for a new pattern to emerge.

A number of experiments demonstrated that animals exhibiting "stimulus-bound" eating, drinking, or gnawing have much in common with animals under the influence of natural drives such as those induced by deprivation. Animals will work to obtain appropriate goal objects and appear willing to tolerate aversive stimulation, such as shock or quinine additives, in order to obtain the desired objects (2). However, the fact that in our experiment animals that were "stimulus-bound" drinkers appear just as motivated to obtain food, for example, raises the question of whether thirst and hunger motives are involved at all (5). Apparently, there is considerably more plasticity in establishing connections between hypothalamic circuits and motivated behavior than commonly advanced interpretations of "stimulus-bound" behavior suggest.

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5. Animals that were switched from "stimulus-bound" drinkers to "stimulus-bound" eaters have been observed to eat the dry pellets in the absence of water almost to the point where they appeared to be choking.
6. Supported by NIH grants M-4529, career scientist award MH-4947, and research grant NSG-437 from NASA. We thank Laura Lande and Debra Singer for assistance.

18 December 1967

8 MARCH 1968

Vocalization of Naive Captive Dolphins in Small Groups

Abstract. *Pure-tone whistles (2403) by four individual dolphins (Delphinus delphis bairdi) were analyzed for duration and the elapse of time before either response by another animal or a repeat whistle by the same animal. Only five major types of whistle emissions were recorded, all stereotyped and each characteristic of the animal emitting it. Only one of the four animals emitted two different whistles, one of which was rare and both of which were stereotyped. A pure-tone chirp and pulsed sounds are discussed. We found no evidence of a dolphin "language," but we present evidence of social response to acoustic signals.*

Many of the small toothed whales have two types of sound emission or phonation (1): a pulsed or broad-band "click" type that is emitted in both echo-ranging and emotional contexts, and a narrow-band or pure-tone "whistle" type that is emitted characteristically only in emotional contexts.

There are strong indications that the Atlantic bottlenosed dolphin *Tursiops truncatus* (Montagu) has a primary "signature" whistle, characteristic of the individual emitting it, that constitutes at least 90 percent—occasionally almost 100 percent—of any individual's whistle repertoire (2). We postulate that this signature whistle may serve primarily to identify its source for the other members of the community.

Many *Tursiops* with which we have worked for as long as 3 years have never changed this basic whistle contour in any major way other than by repetition of the same whistle without a pause in time. A few, however, have at least one different but stereotyped whistle. Thus we believe that any study of cetacean communication that deals with the transfer of information by way of the whistle should begin with this important individualized signature whistle and its minor variants. This and other whistle contours (if any) may then be investigated in straightforward biological terms of age, sex, and physiological condition of the animal, rather than by initial efforts to construct a dolphin "language." Hitherto the latter approach has been commonly pursued with *Tursiops* (3) and currently is being used by other workers in studies of

different odontocete cetacean species.

Analysis of the pure-tone whistles from a group of common dolphins indicates that this species also has a mechanism of a primary signature whistle characteristic of the individual. We report primarily a time-and-contour analysis (4) of 2403 whistles emitted by four common dolphins [*Delphinus delphis bairdi* (Dall)] captured together off Los Angeles, California. Recordings (5) and observations of the small, brightly-colored, possibly immature individuals, one male and three females, were begun 2 days after capture. Initially the animals whistled loudly and in frequent bouts. After 34-day captivity and removal of a female, both the loudness and frequency of occurrence of sound emissions were reduced; recordings were discontinued on day 34.

Among the 1424 whistles of the initial four-animal group, only five whistle contours were recorded (Fig. 1, A-E); all whistles were virtually constant within themselves in contour shape, duration, and frequency modulation (5). Contours 2 and 5 (Table 1) were apparently emitted by the same animal, as they were the only two whistles that never were emitted simultaneously; all other animals showed a strong tendency to "chorus" (6) or to the elicitation of a whistle from a second animal before cessation of the whistle by the first. We have therefore designated contour 5 a secondary whistle of what is arbitrarily termed animal 2; it constituted only 6 percent of all whistles emitted by this animal. We interpret the faint indication of

Table 1. Analysis of 2403 whistles by two groups of captive eastern Pacific common dolphins (*Delphinus delphis bairdi*). Group 1 comprised four dolphins; group 2, three of the same four. Percentages appear in parentheses.

Contour	Average duration (sec)	Whistles (No.) by:	
		Group 1	Group 2
1	0.87	544 (38.2)	0
2	.79	626 (44.0)	295 (30.1)
3	.87	95 (6.7)	448 (45.8)
4	.85	139 (9.8)	199 (20.3)
5	.83	20 (1.4)	37 (3.8)