Stimulation experience and incentive variables as determinants of behavior elicited by hypothalamic stimulation*

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Extensive stimulation experience increased the proportion of hypothalamic electrode sites yielding elicited eating and drinking during electrical stimulation. The great number of stimuli required for some electrode sites, prior to the emergence of elicited eating and drinking, suggests the possibility that changes in neural tissue surrounding electrode sites underlies the appearance of elicited behavior.

A wide variety of behaviors can be elicited by electrical stimulation of the hypothalamus in the rat and other species. Within the areas of the hypothalamus that yield elicited behavior, the majority of electrode sites yield only locomotor-exploratory (LE) behavior as compared to specific consummatory responses such as eating, drinking, copulation, and attack (Cox & Valenstein, 1969). While it is of interest that many hypothalamic electrodes yield specific goal-oriented behavior, it is equally interesting that the majority do not, even though the location of the electrode sites in both cases are anatomically indistinguishable (Cox & Valenstein, 1969). In some cases, essentially identical electrode sites on different sides of the midline, within the same animal, will at one site yield specific consummatory behavior and at the other, LE behavior. Elicited LE behavior is difficult to interpret and may simply be a nonspecific response to brain stimulation. On the other hand, LE behavior may represent the same kind of response as elicited eating and other elicited consummatory behaviors (Rosenquist & Hoebel, 1968) or possibly a precursor of more specific behavior that would appear if appropriate goal objects were available (Christopher & Butter, 1968).

In past studies we have routinely designated electrode sites as LE or negative sites if no specific consummatory behavior could be elicited following the administration of 388 30-sec episodes of

hypothalamic stimulation. However, the failure of some electrode sites to yield specific consummatory behavior after a fixed number of stimuli does not establish that the site is not capable of yielding behavior other than LE behavior. There are behavioral and anatomical commonalities between LE sites and sites yielding specific consummatory behavior. Electrode sites that yield specific behavior will yield LE behavior in the absence of any goal objects, and, in our experience, all sites that yield specific goal-oriented behavior yield LE behavior prior to the emergence of a specific consummatory behavior. The behavioral and anatomical commonalities between sites that yield specific consummatory behavior and sites that yield only LE behavior suggest the possibility that the LE sites could be made to yield specific consummatory behavior if appropriate items were present during stimulation or different stimulation parameters were employed. We chose to explore this possibility by determining if high-incentive goal objects and/or more extensive stimulation experience might result in specific consummatory behavior from sites that previously yielded only LE behavior.

SUBJECTS, SURGERY STIMULATION, AND HISTOLOGY

The Ss were 18 mature male Holtzman albino rats (250 g). Each animal was implanted with two hypothalamic electrodes, one on each side of the midline. The electrodes were bipolar and fabricated of twisted insulated wire (Plastic Products, .01 in. in diam) and were bare of insulation at the crosssectional area of the tips. With the dorsal surface of the skull level between bregma and lambda, the electrodes were positioned 3.5 mm posterior to bregma, 1.5 mm lateral, and 8.5 mm below the top of the

skull. Animals were stimulated with 60-cycle sine wave stimulation. At the end of the experiment, the animals were sacrificed. Their brains were perfused with saline and formalin, and frozen sections (80 microns) were cut and stained with chresylechtviolett.

GENERAL PROCEDURE

After recovery from surgery, the animals were screened to determine if hypothalamic stimulation elicited eating, drinking, or LE behavior. Each animal was placed in a clear Plexiglas chamber provided with Purina Lab Chow and water and given three "standard tests." Each standard test consisted of 20 30-sec stimuli separated by 60-sec interstimulus intervals. Each standard test was separated from another by at least 30 min. If no eating or drinking was observed during initial screening, the animals were stimulated for a 12-h period throughout the night with one 30-sec stimulus delivered once every 5 min. This schedule was repeated a second night if no eating or drinking was observed in a standard test following the first overnight session. If no eating or drinking was observed during a standard test following the second overnight session, the electrode site was classified as LE and was employed in the experiment proper.

Animals with electrode sites meeting the LE criterion were then exposed to additional stimulation so that each received a maximum of 880 stimuli inclusive of the 388 stimuli required for LE designation. The additional stimulation experience consisted of a maximum of three additional overnight stimulation sessions, each followed by a standard test. The stimulation regimen was discontinued once an animal reliably displayed eating or drinking during a standard test following an overnight session.

In Group 1, nine animals received all stimulation experience in the presence of regular Purina Chow and plain tap water. Nine animals in Group 2 received an identical number of stimuli, with the exception that all stimuli beyond the 388 required for LE designation were administered in the presence of a highly palatable food (C/D cat and dog food) and a highly palatable solution of water flavored with saccharin and glucose (Valenstein, Cox, & Kakolewski, 1967). These high-incentive items were employed to increase the frequency of eating and drinking and enhance the likelihood of these behaviors occurring during periods of hypothalamic stimulation. If contiguity of eating and drinking with stimulation play a role in the emergence of elicited eating and drinking, it was expected that the high-incentive group would yield more

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Table 1
Number of Stimuli Administered and Behavior Elicited by Hypothalamic Stimulation

S	Elicited Behavior	Number of Stimuli Before Consummatory Response*	Standard Test	
			Eating	Drinking
Group 1				
33FF	Drinking	544	0	5
99FF	Drinking	534	0	15
1GG	Drinking	698	0	16
4GG	Drinking and Eating	861	1	10
96FF	LE	880		
97FF	LE	880		
8GG	LE	880		
43FF	LE	880		
50FF	LE	880		
Group 2				
49EE	Eating	696	8	0
35EE	Drinking, Eating	696	9	11
18FF	Eating and Drinking	696	13	2
21FF	Drinking and Eating	847	2	7
10FF	LE	880		
15II	LE	880		
13FF	LE	880		
16FF	LE	880		
44II	LE	880		

*Animals were not observed during overnight sessions that preceded standard tests. Consequently, behavior observed during a standard test could have emerged during the overnight session prior to the standard test that yielded specific consummatory behavior.

electrode sites capable of eliciting eating and drinking than would the group exposed to Purina Chow and water.

RESULTS AND DISCUSSION

The number of electrode sites that eventually yielded either elicited eating or drinking or both and the number of stimuli administered prior to the observation of these behaviors during a standard test are presented in Table 1. Table 1 also presents the number of stimuli that elicited behavior during the standard test that yielded elicited eating, drinking, or both. In both groups, four electrode sites that originally yielded only LE behavior subsequently yielded eating, drinking, or both. Thus, 8 of 18 electrodes that initially yielded LE behavior came to yield eating, drinking, or both. The equal frequency of elicited consummatory behavior in both groups indicates that extensive stimulation experience is sufficient to elicit specific goal-oriented behaviors from LE sites and that the addition of high-incentive goal objects does not further increase the number of LE sites eventually yielding specific goal-oriented behavior. The distribution of elicited drinking and eating in the two groups suggests that the experimental conditions favored elicited drinking in Group 1. The conditions determining the preference for a given goal object during hypothalamic stimulation are not known. Consequently, the higher incidence of drinking in Group 1

merits further exploration. Of the four animals displaying specific goal-oriented behavior in the high-incentive group, only one continued to display these elicited behaviors when the diet and fluid were changed to ordinary Purina Lab Chow and tap water. Thus, as in previous work (Valenstein, Cox, & Kakolewski, 1968), the emergence of a behavior in response to hypothalamic stimulation appears, in most cases, to be tied specifically to the goal objects present during the emergence of the response rather than to a general class of acceptable foods in the case of elicited eating or acceptable fluids in the case of elicited drinking.

Histological examination of electrode sites was possible for 17 of the 18 electrode sites.¹ All the electrodes were in a region which has been described previously as containing LE sites as well as electrode sites, yielding specific consummatory behavior with no apparent differential anatomical distribution of the two types of sites (Cox & Valenstein, 1969). The region extends from the posterior margin of the anterior hypothalamic nucleus to the mamillary bodies, from the dorsal edge of the zona incerta to the ventral edge of the hypothalamus, and from the medial edge of the internal capsule to the lateral edge of the ventromedial nucleus. Whether the present results can as well be extended to sites that have thus far yielded only LE behavior requires additional study.

The eight electrode sites that yielded eating and/or drinking in the present study required from 400 to more than 800 stimuli prior to the appearance of these behaviors. The possibility that changes in neural tissue surrounding the electrode site underlies the appearance of eating or drinking is suggested by the great number of stimuli required prior to their emergence in response to hypothalamic stimulation. Goddard (1969) has reported permanent changes in brain function as a result of periodic brain stimulation over a period of several days or weeks. Wise (1968) has demonstrated that the stimulation thresholds for elicited behaviors decline as a function of repeated stimulation and has offered the hypothesis that stimulation threshold changes reflect increased sensitivity of neural systems mediating the particular response elicited by electrical stimulation. The appearance of a specific consummatory response after many stimulation episodes is consistent with Wise's hypothesis. What seems to be clear is that the failure to elicit consummatory behavior from sites yielding LE behavior does not necessarily reflect some permanent functional characteristic of an electrode site. The possibility is strengthened, in light of the present results, that with sufficient stimulation experience all hypothalamic sites that yield LE behavior may be capable of yielding specific appetitive behavior.

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NOTE

1. 99FF was sacrificed without histology due to a loose electrode pedestal.