# MOTIVATIONAL PROPERTIES OF HYPOTHALAMIC STIMULATION IN CATS

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UDC 612.826.4-063-07:612.821.3

In experiments to study the motivational properties of "true rage," "flight," and "stalking attack" responses evoked by electrical stimulation of the hypothalamus it was found that the external manifestations of behavioral responses evoked by hypothalamic stimulation in cats do not necessarily serve as a definitive criterion for their classification among particular biological types. Unlike the "true rage" response, the "flight" response can act as reinforcement of a conditioned-reflex removal response and has "punishing" properties. During "flight" and "stalking attack" responses the phenomenon of self-stimulation of corresponding points of the hypothalamus was observed. The beginning and continuation of stimulation in these cases can evoke biphasic positive-negative motivational swings.

Hypothalamic stimulation in cats evokes coordinated responses of different modalities [1-3, 6, 7]. Aggressive-defensive manifestations such as "rage," "flight," "attack," and so on are particularly demonstrative. The stereotyped nature of evoked behavioral responses, their strict dependence on the parameters of stimulation, and the presence of components suitable for quantitative analysis has led to their use as tests for the study of psychotropic drugs. However, the categorization of concrete responses as "rage," "anxiety," and so on is based on subjective assessment of the external manifestations.

Proof that the emotions which arise are genuine can be obtained by the use of brain stimulation as reinforcement in various experimental situations of the "approach–avoidance" type. The object of the present investigation was to assess the motivational properties of hypothalamic stimulation in cats by means of operant methods.

## EXPERIMENTAL METHOD

Cats weighing 2.5-4 kg with "true rage," "flight," and "stalking attack" responses were used. Details of the technique of implantation of the electrodes, parameters of stimulation, and response types were fully described previously [3]. A diagram of the localization of the electrodes in the experimental animals is given in Fig. 1.

In the experiments of group 1 hypothalamic stimulation replaced natural reinforcement in an instrumental food-getting response. These experiments were carried out on animals previously trained in pressing a pedal to obtain food under constant reinforcement conditions [5].

In the experiments of group 2 a conditioned-reflex avoidance response was first developed in the cats; the animals jumped over a barrier or onto a special platform in response to the conditioning stimulus in order to avoid receiving an electric shock to the limbs. The animals were then placed in the same chamber and, without presentation of the conditioning stimulus, hypothalamic stimulation was applied; this could be disconnected by the cat itself if it performed the conditioned-reflex movement (the removal response). Some animals were trained to remove the hypothalamic stimulation without preliminary training with nociceptive reinforcement.

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Department of Pharmacology, Academician I. P. Pavlov First Leningrad Medical Institute. (Presented by Academician of the Academy of Medical Sciences of the USSR S. V. Anichkov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 75, No. 3, pp. 13-16, March, 1973. Original article submitted November 2, 1971.

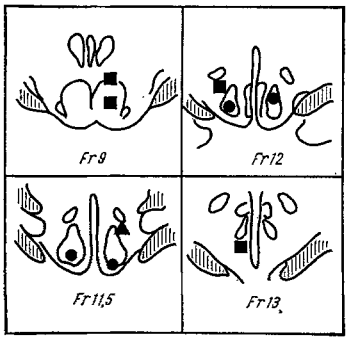


Fig. 1

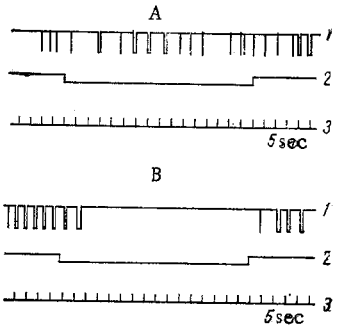


Fig. 2

Fig. 1. Localization of electrodes and types of evoked responses. Circle represents "rage" response; square) "flight" response; triangle) "stalking attack" response.

Fig. 2. Effect of hypothalamic stimulation evoking responses of "rage" (A) and "flight" (B) on instrumental food-getting response: 1) pressing on pedal; 2) marker of period of hypothalamic stimulation (each pressure activates electrical stimulation); 3) time marker (5 sec).

In individual experiments the "punishing" properties of electrical hypothalamic stimulation were analyzed. These were assessed (a) with reference to preservation of the food-getting response of the hungry cat during hypothalamic stimulation at the moment of approaching the feeding bowl and (b) with respect to maintenance of the instrumental food-getting response when pressure on the pedal or approaching the feeding bowl was accompanied by brief hypothalamic stimulation.

## EXPERIMENTAL RESULTS

The negative-reinforcing properties of "true rage," evoked by activation of particular hypothalamic structures, were investigated in experiments with avoidance and removal responses. During hypothalamic stimulation in the chamber in which a response to the ringing of a bell had been developed and stabilized with the use of nociceptive reinforcement, activation of the operant reflex was not observed even after several dozen hypothalamic stimulations. The intensity of hypothalamic activation was sufficient to reproduce the whole expressive stereotype of the rage response, but the ability to remove the hypothalamic stimulation (by jumping across the barrier or onto the platform) was not developed.

Stimulation evoking a "true rage" response did not have a punishing effect. The hungry animal continued to eat the food despite the fact that approaching the feeding bowl and taking the food were accompanied by hypothalamic stimulation above the threshold of intensity for vocal manifestations. Similar results were obtained in experiments to evoke a conditioned food-getting response (Fig. 2A). When the animal pressed on the lever, it switched on the brain stimulation which continued so long as the animal's paw remained on the pedal. The intensity of hypothalamic stimulation was above the threshold for vocal manifestations and in some cases when the electric current was switched on for longer periods growling and hissing were observed. Nevertheless, despite the expressive picture of "rage" in the animals' general behavior, the instrumental response remained substantially unchanged.

Positive-reinforcing properties of the "rage" response were investigated in experiments with extinction of the food-getting reflex on replacement of the food reinforcement by electrical stimulation of the hypothalamus. In control experiments extinction of the food-getting reflex on withholding the food reinforcement took place in the course of 5-10 min. On replacement of the food reinforcement by brief (1 sec) electrical stimulation of the hypothalamus at optimal intensity for the appearance of a "rage" response there was no significant change in the time of extinction compared with the control (Fig. 3A). It is interesting to note that in the first 2 or 3 sessions in which the reflex was extinguished and food reinforcement replaced by electrical stimulation of the brain, a slight degree of self-stimulation could be observed.

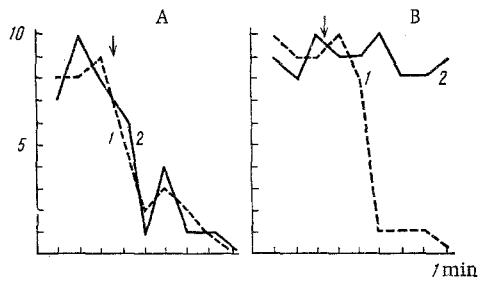


Fig. 3. Instrumental food-getting response during replacement of food reinforcement by electrical stimulation of the hypothalamus evoking responses of "rage" (A) and "flight" (B). Ordinate, number of pressures on pedal per minute; abscissa, time (in min); 1) control with extinction of reflex on withholding reinforcement, 2) replacement of food reinforcement by electrical stimulation. Moment of withdrawal of food reinforcement (control) and its replacement by electrical stimulation marked by arrow.

Hypothalamic stimulation in a situation in which a defensive conditioned reflex had been formed previously and at the optimal intensity for the appearance of a "flight" response led to rapid activation of the previously formed flight response, and the animal quickly learned to disconnect the central stimulation. This skill was also formed in cats without preliminary training in the reflex of removing the nociceptive response. Stimulation of the "flight" zone has punishing properties. Brief stimulation of the brain at optimal intensity at the time of pressing on the pedal led to the rapid suppression of the food-getting reflex in the hungry animal (Fig. 2B). If a feeding bowl containing meat was placed before the animals and hypothalamic stimulation carried out as they approached the bowl and took the food, a response of avoiding the feeding bowl quickly developed during repetition of the stimulation.

However, the "flight" response may also possess more complex motivational properties. The course of extinction of the food-getting reflex on replacement of the food reinforcement by electrical stimulation of the hypothalamus is shown in Fig. 3B. As the figure shows, extinction of the reflex did not take place in this animal and a self-stimulation response developed. Consequently, hypothalamic stimulation evoking "flight" may have ambivalent motivational properties, as was confirmed by experiments using a special technique: the animal was able to activate the stimulation by pressing on a lever and to disconnect it by jumping across the barrier. Under these conditions the animal reproduced "pressure–jumping" cycles and the latent period of disconnection of the stimulation was reduced with an increase in its intensity. The mechanism of self-stimulation in these ambivalent responses evidently cannot be attributed entirely to the reinforcing properties of electrical hypothalamic stimulation. The aftereffect following removal of the stimulus probably acted as reinforcement. This is confirmed by the fact that the ability to disconnect central stimulation was preserved at all thresholds evoking self-stimulation.

In one of the cats with a "stalking attack" response, to use the term employed by Flynn [4], marked self-stimulation was observed and its intensity depended on the degree of satiation, increasing in the hungry animal. In this case hypothalamic stimulation acquired properties of aversion, and it could act as reinforcement for the flight response only with an increase in the intensity of the stimulus.

It can be concluded from these results that the external manifestations of responses evoked by central stimulation do not provide a definitive criterion for their identification by analogy with natural response. For instance, the "flight" response which is usually linked with the emotional state of fear may also have emotionally positive properties if they are judged from the self-stimulation response. This fact must be taken into consideration during physiological investigations of the behavioral effects of stimulation of different zones of the brain and, in particular, in the study of the action of psychotropic drugs, for which precise and unambiguous models of emotional states are necessary.

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