matically comparable to those of experiments concerning other response mechanisms (such as the galvanic skin response) for which continuous measures have been devised. Finally, and most important, the magnitude measure apparently provides the most veridical quantitative representation of the physiological process by which an eyeblink occurs. As such, its use can only assist in integrating the psychological and physiological phenomena which define classical conditioning.

H. S. PENNYPACKER

Department of Psychology,
University of Florida, Gainesville

References and Notes

1. The term *magnitude* has been used by Humphreys [*J. Gen. Psychol.* **29**, 101 (1939)] to denote the average amplitude (including zeroes) of a finite set of conditioned responses. Since my use of the term is with reference to properties of a single response, the likelihood of confusion would seem to be minimal.
2. Grason-Stadler Model E4580 Multiple Stimulus projector.
3. H. S. Pennypacker, *J. Exptl. Psychol.* **67**, 33 (1964).
4. I thank Ronald Mourant and Stuart Fabric for their assistance in tabulating and analyzing the data.
5. Q. McNemar, *Psychological Statistics* (Wiley, New York, 1955), pp. 156–160.
6. Supported in part by USPHS grant M 5063. An earlier version of this report was presented at the Psychonomic Society, Philadelphia, 1963. I thank H. D. Kimmel, R. B. Masterson, and W. F. Prokasy, Jr., for their helpful comments.

13 March 1964

Attack Elicited by Stimulation of the Thalamus of Cats

Abstract. *Electrical stimulation of sites in the medial thalamus leads to attack upon rats. This attack summates with attack elicited by hypothalamic stimulation. Stimulation of other thalamic sites suppresses hypothalamic attack, while excitation of still others facilitates it.*

The role of the medial thalamus in emotional functioning is not clearly established. In man, aside from other effects, destruction of the dorsal medial nucleus appears to reduce aggression and anxiety at least temporarily (*1*). In laboratory animals, the same procedure has yielded increased (*2*), reduced (*3*), or unchanged (*4*) emotional reactivity. Electrical stimulation of the dorsomedial nucleus induces fear-like responses (*5*), and excitation of midline thalamic nuclei has induced a high level of excitement in at least one instance (*6*). In our study, stimulation of different portions of the midline thalamic structures has been found (i) to elicit attack, (ii) to summate with attacks elicited from the hypothalamus, and (iii) to suppress this same response. The different loci for these effects may explain the discrepancies in previous results.

Table 1. Mean latent period between stimulation of the medial thalamus and attack.

Cat	No. of trials	Mean latency (sec)	S.D. (sec)	Stimulus intensity (ma)
6143M	25	6.8	2.9	0.60
11193M	20	4.7	1.9	0.60
11133M	21	7.2	2.8	0.40
11183M	20	4.3	0.9	0.30

Nine cats had electrodes implanted aseptically in regions of the lateral hypothalamus where stimulation regularly elicited attack. In the same operation calibrated guide tubes through which calibrated electrodes were later lowered to the thalamus were also mounted on the skull.

Of these nine cats, only one would attack a rat placed in its cage without being stimulated electrically. On the other hand, all nine would attack a rat savagely when stimulated electrically through the hypothalamic electrodes. Deeply anesthetized rats were used in this experiment. Dummies and stuffed rats are unsuitable, since the response deteriorates when they are the attack objects.

The hypothalamic stimulation consisted of biphasic square waves, each lasting 2.0 msec and occurring 62.5 times per second. Stimulation was continued until the cat bit the rat or in the case of the attack being suppressed, for 30 seconds.

Movable electrodes were used in the exploration of the thalamus. Unintentional movement of these electrodes in the active unanesthetized cat was avoided by placing a plastic cap over them and by making an indirect connection to the leads.

With the movable electrode, testing usually began at the level of the cingulate gyrus and proceeded ventrally in small steps. At each step, three observations were made: the effect of stimulating the test point, the effect of stimulating the lateral hypothalamus, and the effect of stimulating both test point and hypothalamus in combination. During the combined stimulation, the individual pulses to the hypothalamus took place 6 msec before those to the thalamus, so as to avoid stimulating the area between the hypothalamus and thalamus.

When an effect was found that was relevant to our study, the site was stimulated at intervals for 1 hour, and the electrode was then cemented in place. The currents required to produce an effect were greater in the stage when the electrode was being moved than after it had been fixed in place for a week.

The positions of the tips of both the movable electrodes and the ones

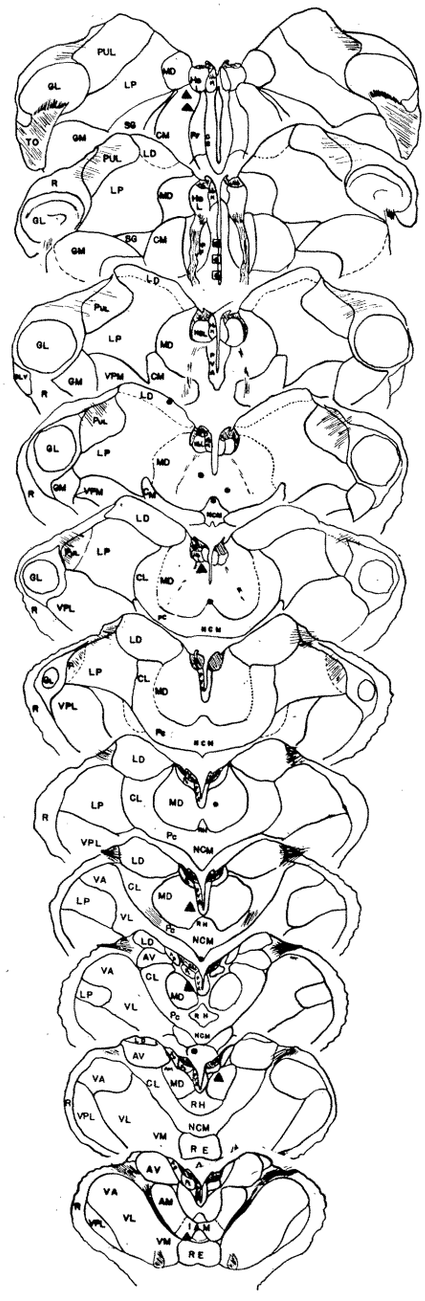

Fig. 1. Points in the thalamus giving rise to attack (dots), suppression of hypothalamic attack (triangles), and facilitation of hypothalamic attack (enclosed dots). Sections begin at F 11.5 and continue posteriorly at 0.5-mm intervals. Points were determined histologically.

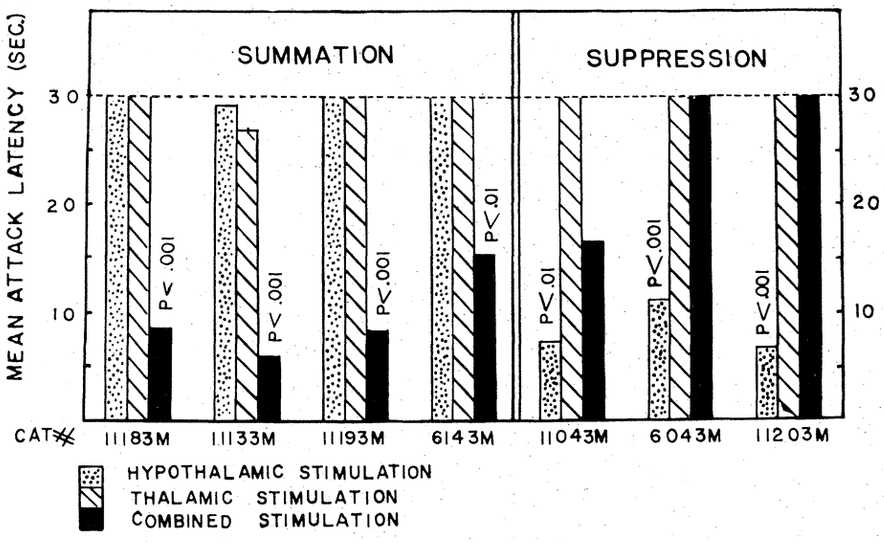

Fig. 2. Mean latencies to attack showing thalamic-hypothalamic interaction. In the absence of attack, stimulation was not continued beyond 30 seconds. For statistical analysis it was assumed that trials in which no attacks were made ended in attack at that limit.

implanted in the initial operation were verified by studying the brains in histological sections that were stained alternately for nerve cells and for myelinated fibers. To facilitate histological verification of stimulated sites, the movable electrode was never moved upward in its track.

Attack somewhat similar to that elicited by excitation of the lateral hypothalamus (*7*) was produced by stimulation of sites in the midline nuclei of the thalamus and the medial portion of the dorsal medial nucleus (Fig. 1 and Table 1). Attack was heralded by pupillary dilation and piloerection which varied from weak to strong in different cats. Hissing, vocalization, arching of the back, and striking movements were never observed. A mild crouching might occur before the attack was launched, but it was not a constant feature of the pattern. Attack often developed from a sitting or recumbent position. The location of the target affected the particular form of the assault. With the rat close by, after a brief latent period the cat would stoop abruptly and launch a savage biting attack, usually using his paws to restrain the rat. With the rat at a distance, the typical movement was a sudden, low to the ground, direct-line approach followed by a hard-biting attack. If the rat were out of view, gross movements often did not occur until the rat appeared in the cat's field of vision.

Combined stimulation of the thalamic and hypothalamic sites summated to produce biting attack, even when the levels of stimulation to either point alone were below threshold for attack (Fig. 2). In one exceptional case, a thalamic attack point and a hypothalamic attack point, when stimulated in combination, had mutually occlusive effects. Careful adjustment of stimulating currents, which were well above threshold for either site alone, could, when combined, produce a remarkably quiescent but alert state which gave way to savage attack whenever stimulation of either point was discontinued. Other thalamic points (Fig. 1) which produced no gross behavior when stimulated alone facilitate attack elicited by stimulation of the hypothalamus.

Strong suppression, often complete block (Fig. 2), was produced by stimulation of other midline thalamic points (Fig. 1). During combined stimulation the responses fell largely into three categories: (i) passive attending to the rat, (ii) backing off from the rat, or (iii) abortive attack breaking off before contact and ending in retreat to a distant corner. In two cats the stimulation of the thalamus alone produced crouching, but the animals appeared alert, since they followed visual stimuli accurately and often moved away from the rat, watching it from across the chamber. A strong fear-like response was observed from a point in the dorsal medial nucleus, as reported by Roberts (*5*). This reaction was much more intense than the responses just described. The suppression effect was not a consequence of an arrest reaction such as those encountered in the course of stimulating sites other than those considered in this paper. In the two other cats showing the suppression, stimulation of the suppression points alone elicited only a mild alerting and a momentary interruption of on-going behavior. One of these cats attacked rats spontaneously. The spontaneous attacks were completely suppressed during thalamic stimulation and often immediately resumed upon the end of stimulation.

Our study adds to the accumulating evidence implicating midline thalamic structures in emotional behavior.

MALCOLM F. MACDONNELL
JOHN P. FLYNN
Department of Psychiatry,
Yale University School of Medicine,
New Haven, Connecticut

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