JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 9, NUMBER 4 JULY, 1966

TRANSFER OF AN ESCAPE RESPONSE FROM TAIL SHOCK TO BRAIN-STIMULATED ATTACK BEHAVIOR[1]

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Nine cats, each with two hypothalamic electrodes in sites which when stimulated produced either quiet attack or attack accompanied by certain forms of vocalization, were trained to escape from tail shock by jumping onto a stool. They were then tested for transfer of the escape response to brain stimulation. Stimulation of the seven sites that yielded quiet biting attack did not elicit the learned response of jumping onto the stool. Stimulation of eight of the 11 sites that yielded attack accompanied by vocalization did elicit the learned response. It was concluded that attack behavior elicited by brain stimulation should not be considered a special case of the response to aversive stimulation, but that attack and response to aversive stimulation involve independent but overlapping systems.

Attack upon a rat can be elicited by electrical stimulation of certain brain sites in cats that do not spontaneously attack rats (Wasman and Flynn, 1962). Attack can also be elicited by electrical shock to the feet of cats (Ulrich, Wolff, and Azrin, 1964). Since cats learn to escape from shock to the feet or tail, the question was asked whether or not cats that learned such an escape response would show transfer with respect to hypothalamic stimulation at sites from which attack could be elicited.

One bit of evidence is relevant to this question. Transfer was observed in the single cat tested by Nakao (1958). This cat had learned to push a paddle to escape grid shock, and it similarly pushed the paddle to terminate electrical stimulation to the brain. The electrical stimulation would elicit attack accompanied by marked display (Hess, 1928; Hess and Brugger, 1943; Hunsperger, 1956). However, as the test trials progressed, the time from the onset of brain stimulation until the cat pushed the paddle increased rather than decreased. A possible explanation may lie in the fact that grid shock trials were discontinued when brain stimulation trials began. The present procedure interspersed the brain stimulation trials between tail-shock trials to maximize the possibility of transfer.

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METHOD

The number of trials on which a cat jumped onto a stool in response to an appropriate hypothalamic stimulus was determined. The cats were then trained to jump onto the stool to escape tail shock. The frequency of jumping responses to hypothalamic stimulation was then redetermined and a comparison of this score with that obtained before tail-shock training was used to assess transfer effects.

Subjects and Apparatus

Nine cats that did not attack rats spontaneously were used. Each cat was placed under anesthesia, and 12 stainless steel electrodes were aseptically implanted in its brain. Each electrode was 0.6 mm in diameter, insulated with paint, and had 0.6 mm of its tip exposed. Two electrodes per cat were chosen for transfer testing. Aside from one exception, stimulation of the electrodes selected yielded an attack upon a rat. The attack, which consisted of either biting the anesthetized rat or striking it with unsheathed claws, was accompanied either by marked display, or by little display. The display consisted of vocalization, usually associated with piloerection, ear retraction, and baring of the teeth. The other form of attack was discernible primarily because the cat bit the rat, usually at the back of its neck. Wherever possible, one electrode associated with attack accompanied by display, and one electrode associated with quiet biting attack were chosen. Of the 18 electrodes tested for transfer, stimulation yielded quiet biting attack from seven electrodes and attack associated with vocalization from 11.

The stimulation to the brain was the same as that which would elicit attack. The particular stimulus for each electrode was determined before the control trials, and that intensity was maintained throughout the experiment. The stimulus consisted of 2 msec biphasic square waves at a frequency of 60 cps. An approximation to a constant current was obtained by placing a 60,000 ohm resistor in series with the cat's electrodes. The stimulation was monopolar, the indifferent being an electrode in the table of the skull. In two cases (B_2, I_2) the stimulation was bipolar. The peak-to-peak current itself was measured by observing on a calibrated oscilloscope the voltage drop across a 100 ohm resistor (accurate to 1%), which was also in series with the cat's electrodes. Current values for the individual electrodes ranged from .20 to .80 ma.

The shock to the cat's tail was applied between two small plates taped to the base of the tail. It was a 60 cps sine wave current, measured across a 100 ohm precision resistor, and of sufficient intensity just to elicit hissing or meowing. Its intensity varied from one cat to another in the range of 1.5 to 3.0 ma. The shock was intermittent: 0.5 sec on, 0.5 sec off.

In practice, on each trial of brain stimulation or tail shock, the cat was placed in a starting box with its head toward the door. Stimulation was then begun. As soon as the cat made some overt response to the stimulus, such as moving or meowing, the door of the starting box was opened (usually within 1 or 2 sec). The cat could either remain in the starting box, which measured 15 in. in length, or it could go into a Y-maze, one arm of which contained a stool. The distance from the door to the far end of the Y-maze measured 21 in., each arm being 10 in. in width. The stool, situated in the right arm of the maze was 8 in. high, and 9 by 9 in. on the side. The cat was considered to have made a response when it supported itself on the stool with no leg touching the floor. The stimulus to the tail ceased when this response occurred.

Two response measures were recorded: the occurrence of a response and its latency, measured from the onset of stimulation. If no response occurred, the time until the end of stimulation was recorded. The latency measure was determined by a stopwatch. The reliability coefficient for a similar determination, the attack latency, was found to be .98 and .94 (Egger and Flynn, 1963). One point might be noted about this measure. After onset of stimulation, the opening of the starting door was delayed until an overt response was made. The delay guaranteed that the response would be an escape response rather than an avoidance response.

Procedure

The general plan was first to determine the number of trials in which responses to brain stimulation alone occurred. The animal was then trained with tail shock alone. After it had reached criterion, it was tested for transfer to brain stimulation alone. During transfer testing, tail shock trials were interspersed between the test trials of brain stimulation.

The trials made before escape training with shock are the control trials. In the control trials, only stimulation to the hypothalamus occurred. The response observed was getting onto the stool. Twenty trials were devoted to stimulation at each electrode, of which there were two in each cat, for a total of 40 trials per cat. Trials were held in two daily sessions with the order of stimulation of placements 1 and 2 being in a 1-2-2-1 order the first session and 2-1-1-2 order the second session. During these trials the duration of brain stimulation was fixed at 15 sec, irrespective of performance. The number of trials on which the cat jumped onto the stool was counted, and time from onset of stimulation to the response was noted. These control trials were necessary because the cat moves about when stimulated at hypothalamic sites and there was a certain probability that it would climb onto the stool.

The tail shock trials are designated learning trials. During these trials the cat learned to terminate tail shock by jumping onto the stool. No brain stimulation occurred. The criterion for learning was 10 consecutive trials in which the cat had all four paws upon the stool within less than 10 sec from shock onset. Forty-one to 134 trials were required by individual cats to reach this criterion.

The transfer trials are similar to the control trials, consisting of brain stimulation only, which was continued for 15 sec irrespective of performance. However, before the transfer trials the cat was given a series of tail shock trials to see that it had maintained the learning criterion. Tail shock trials were alternated with brain stimulation trials. Transfer trials were held in two sessions similar to the control trial sessions, except that tail-shock trials ("s") were interspersed with brain stimulation trials at placements 1 and 2 in a 1-s-2-s-2-s-1 order during the first session and 2-s-1-s-1-s-2 order during the second. Again, each hypothalamic placement was stimulated 20 times. Records were kept of the number of trials on which a response occurred and of the latency of each response.

Four minutes elapsed between each trial.

In the course of the sessions involving the transfer trials, an individual tail-shock trial occasionally lasted more than 10 sec. In this case, transfer trials were discontinued, tail-shock trials were run until the cat had reached criterion again, and the transfer trial session was repeated from the beginning.

It was necessary to repeat the experiment in three instances. Cat A no longer attacked the rat consistently at the end of the experiment when stimulated via electrode 2 at the first intensity. The experiment was repeated at a higher effective intensity. Cats F and G, when stimulated through their individual electrodes 2, faced the experimenter on many trials, rather than turning to jump onto the stool. The experiment was rerun with the experimenter out of the cat's sight.

At the end of the experiment, an anesthetized rat was placed in the maze, and each cat was stimulated 10 times at each hypothalamic site used in the experiment. Stimulation was at the same intensity as used in the experimental procedure. The mean latency of attack on the rat was determined from these trials.

In addition, the cats were tested with 10 trials of tail shock at the intensity used during the experimental procedure, again with an anesthetized rat present in the maze to determine if they would attack the rat in response to the tail shock.

During the experiment, the following behavioral effects elicited by hypothalamic stimulation and by shock to the tail were observed and recorded: biting or striking the rat, hissing, spitting, growling, meowing, panting, pupil dilation, piloerection, urination, defecation, contralateral turning, ear retraction, rigid extension of forelimbs, and eating of horsemeat.

At the end of the experiments the cats were anesthetized, and perfused first with a physiological saline solution and then with 10% formalin. The brains were cut into alternate 50 and 100 micra sections. The 50 micra sections were stained for myelinated fibers, and the 100 micra sections for cells. The sites of the electrodes tips were placed on the sections of Jasper and Ajmone-Marsan's atlas.

RESULTS

Transfer is demonstrated in this experiment when the number of trials on which a cat jumped onto a stool when the hypothalamus alone was stimulated—after having learned to terminate tail shock by jumping onto the same stool—significantly exceeds the number of trials in which it made the same response to hypothalamic stimulation alone before learning. Analogous differences in latencies between control and transfer trials also demonstrate transfer.

Table 1 contains the data obtained in the control and transfer trials for each cat and for each electrode, together with the vocalization occurring when the cat was stimulated. The maximum number of responses is 20, and the longest possible latency is 15 sec.

Occurrence of transfer is associated with vocalization, and the results have been presented in relationship to vocalization in Fig. 1 and 2.

In Fig. 1, the number of trials on which a cat jumped upon a stool in response to hypothalamic stimulation alone, before learning (control trials) and subsequent to learning (experimental or transfer trials), are given for each electrode in each cat. Figure 2 is a similar presentation of the latencies.

In those instances in which stimulation elicited attack without vocalization (*i.e.*, E1, A1, A2, I1, G1, C1, and B1), there is no evidence of transfer. On the other hand, transfer did occur when stimulation elicited vocalization as well as attack (*i.e.*, H1, F1, D2, B2, F2, H2, G2, I2). However, the occurrence of vocalization was not always associated with transfer (*i.e.*, D1, C2, E2).

The form of vocalization most regularly associated with transfer was growling in combination with hissing or spitting or both (*i.e.*,

Table 1

Vocalization, Control, and Transfer Performance for Each Cat

Cat	*Electrode*	*Vocalization****	*Responses* Control	*Responses* Transfer	*Latencies* Control	*Latencies* Transfer
A	1	none	0	1	15.0	14.8
	2	none	0	2	15.0	14.5
B	1	none	8**	0	13.3**	15.0
	2	H S M G	2	16**	14.3	8.8**
C	1	none	0	0	15.0	15.0
	2	hissing	3	1	14.2	14.9
D	1	hissing	1	0	14.7	15.0
	2	S M G	0	18**	15.0	7.3**
E	1	none	0	0	15.0	15.0
	2	meowing	0	0	15.0	15.0
F	1	meowing	0	13**	15.0	9.0**
	2	H S G	1	8**	14.8	11.9**
G	1	none	7	8	13.8	13.4
	2	H G	2	17**	14.4	10.5**
H	1	meowing	4	10*	13.8	13.0
	2	H S G	0	14**	15.0	6.9**
I	1	none	0	1	15.0	14.9
	2	H G	0	8**	15.0	11.2**

* Probability less than .05 by chi square test.

** Probability less than .01 by chi square test in the case of responses and by t test for paired difference in the case of latency measures.

*** H = hissing, S = spitting, G = growling, M = meowing.

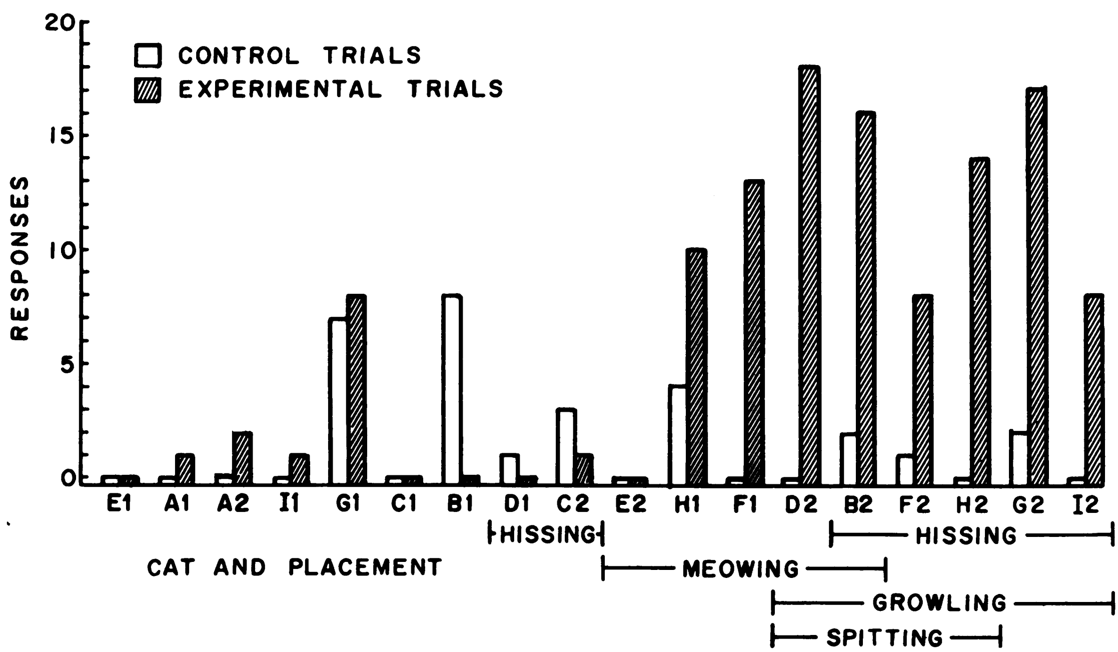

Fig. 1. The control trials are the number of trials on which each cat, when stimulated through electrode 1 or 2, got up on a stool before learning. The experimental trials are similar trials after learning to escape tail shock by getting on the same stool. Transfer has occurred when the experimental trials significantly exceed the control trials. The occurrence of transfer is related to the vocalization observed when the cat is stimulated in the brain.

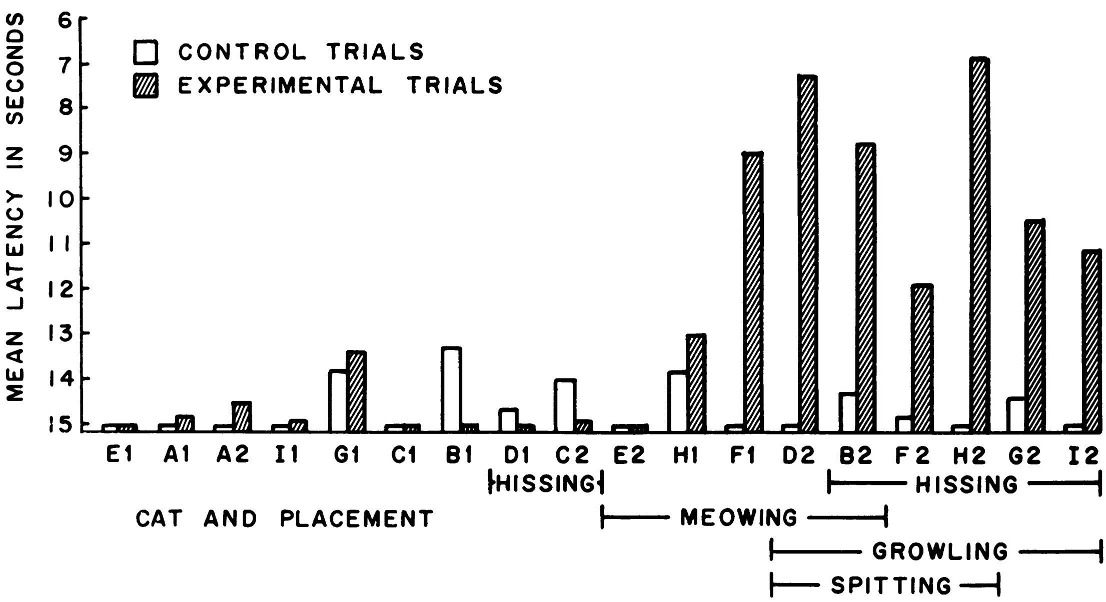

Fig. 2. This figure is analogous to Fig. 1. The mean control latency is the time from the start of brain stimulation through a particular electrode until the cat got on a stool before learning. If it never got on, the latency was taken as 15 sec, the time at which stimulation ended. The mean experimental latency is the same time but after the cat had learned to terminate a shock to the tail by going to the stool. The occurrence of transfer is related to the form of vocalization observed when the brain alone was stimulated. The different forms of vocalization elicited by the brain stimulation are shown for each cat at each placement.

D2, B2, F2, H2, G2, I2). Hissing by itself was not associated with transfer (*i.e.*, D1, C2), while meowing alone bore no constant relationship to transfer.

Other behavioral effects were correlated with transfer, though not as well as vocalization. Stimulation of all five placements which produced a rigid extension of the limbs ("Halloween stance") also produced transfer (B2, H2, D2, G2, F2). Transfer also occurred in all three cases where ear retraction was observed (H2, G2, F2). Transfer occurred in all three cases where the mode of attack included striking (H2, D2, G2). Transfer was not correlated with pupil dilation, piloerection, or urination. Biting without swallowing of horsemeat (A1, A2, G1) and panting (E1, D1, C2) and contralateral turning (E1, I1, D1) occurred only at placements where there was no transfer.

Four cats (B, D, G, I) showed transfer from stimulation of one electrode, but not from the other, so both principal results have been obtained within the same individual.

The current used initially to elicit attack, and then used on both the control and transfer trials, is indicated for each placement in Table 2. The mode of attack and the mean latency of attack on the rat also are indicated.

The control trials were separated from the transfer trials by one or more learning sessions during which each cat learned to jump onto the stool to escape tail shock. The usual intensity of tail shock, the number of trials (including the 10 criterion trials) to reach the criterion of learning, and the mean latency of the response to tail shock during the sessions in which the transfer trials were run, are given for each cat in Table 3.

Seven of the nine cats bit the anesthetized rat when stimulated with tail shock alone. This activity conformed with the general observation that attack can be elicited by electric shock.

Histological results are presented in Fig. 3. Placements where stimulation produced transfer tended to be more medially situated in the hypothalamus as compared with placements where stimulation produced no transfer. Placements I2, D2, G2, F1, and F2 were the most medial and all showed transfer. All of the other placements which showed transfer impinged on the fornix (H1, H2, B2), though several other placements which impinged on the fornix did not show transfer (E2, D1). The most lateral placements (C1, G1, I1, and B1) showed no transfer.

Table 2

Current Intensity and Attack Performance for Each Cat

Cat	Electrode	Current (ma.)	Mode of attack	Mean attack latency (sec.)
A	1	.60	biting	8.7
	2	.55	biting	6.0
B	1	.55	biting	10.3
	2	.45	biting	15.7
C	1	.60	biting	15.0
	2	.50	biting	7.3
D	1	.70	biting	4.5
	2	.80	biting/striking	10.4
E	1	.40	biting	10.0
	2	.34	biting	15.7
F	1	.50	biting	7.6
	2	.30	none on rat	
G	1	.30	biting	12.4
	2	.45	striking	17.0
H	1	.20	biting	15.8
	2	.30	biting/striking	5.0
I	1	.35	biting	13.3
	2	.30	biting	3.3

DISCUSSION

The original question asked was whether or not cats that learned to escape tail shock would transfer this same response to stimulation of hypothalamic sites from which attack could be elicited. The answer depends upon the type of attack elicited by hypothalamic stimulation: stimulation of sites that yield quiet biting attack does not lead to transfer, while stimulation of sites eliciting attack plus certain forms of vocalization and display does lead to transfer.

The present method seems more likely than other methods to elicit similar responses from brain stimulation and from shock. In a previous study (Nakao, 1958), escape and compartment preference tasks were used, in addition to a transfer task, to investigate the characteristics of the cat's response to brain stimulation. Nakao's "aggressive" cats behaved similarly to those in the present experiment in which transfer took place. He describes his aggressive cats as showing mydriasis, strong retraction of the ears, arching of the back, extension of the legs, and as snarling, hissing, attacking the experimenter if he moved, and biting a proffered stick. The techniques he employed without success were training cats to push a paddle to terminate hypothalamic stimulation and a compartment preference test. In the latter, preference was determined first. The animal

Table 3

Tail Shock Current Intensity, Learning Trials, and Tail Shock Performance During Transfer

Cat	Tail shock intensity (ma.)	Trials to criterion	Mean response latency (sec.)
A	1.5	41	2.6
B	3.0	132	2.5
C	2.5	65	7.0
D	2.2	71	3.4
E	2.0	64	4.9
F	2.5	60	5.7
G	2.0	134	4.5
H	2.0	73	3.4
I	2.0	48	4.7

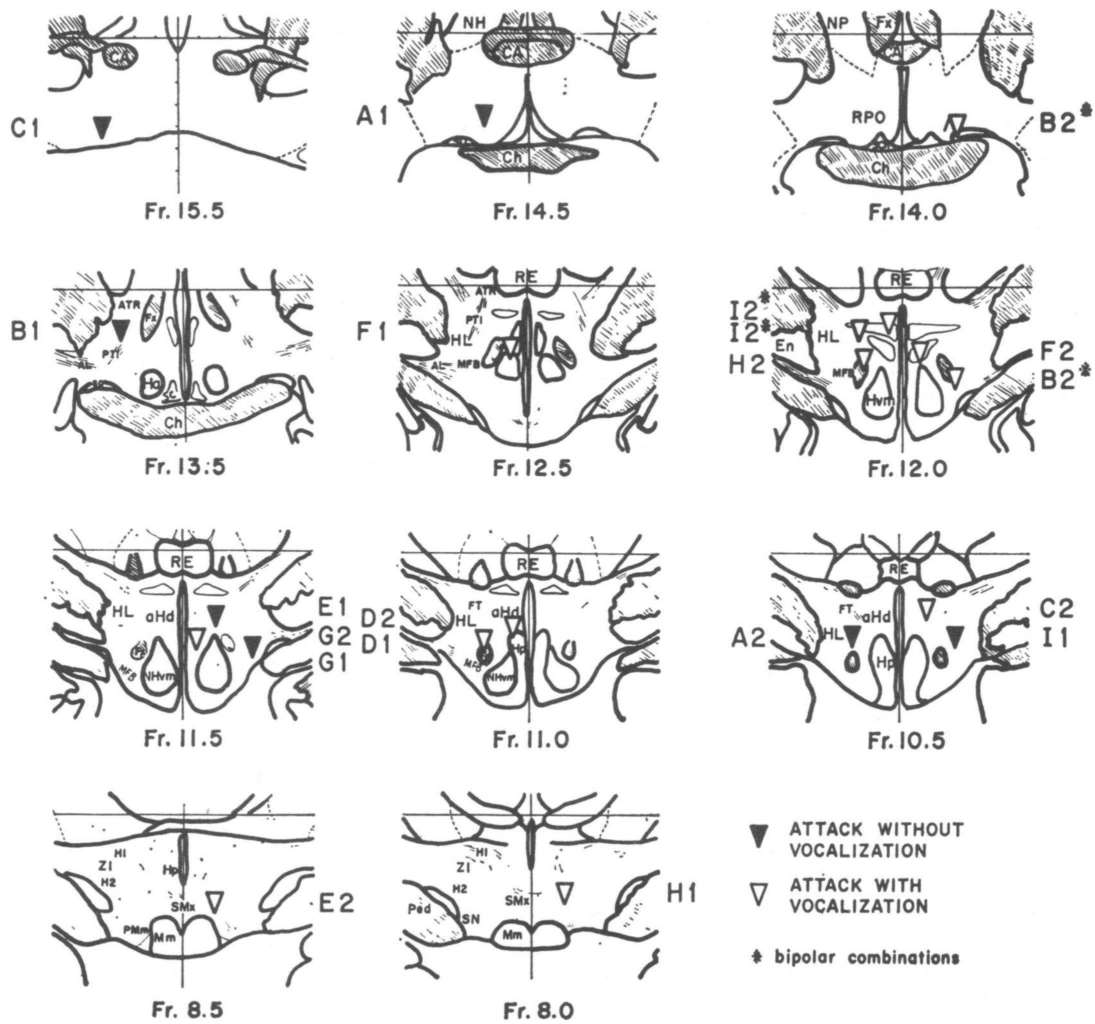

Fig. 3. The sites at which stimulation elicited attack from a cat are shown. Transfer did not occur from those sites which did not elicit vocalization. Transfer occurred from the sites from which vocalization was elicited with the exception of sites D1, C2, and E2.

was then stimulated in the compartment, and then preference was redetermined. In the cats with aggressive reactions, there was no learning or change in preference. These tasks, however, were readily learned by other cats which jumped to the top of the cage on being stimulated in the hypothalamus. It was only with the transfer task that Nakao obtained results from an "aggressive" cat similar to those which would be expected from shock.

Even though the cats which are stimulated at placements yielding attack with several forms of vocalization do react to the hypothalamic stimulation as they do to tail shock, it should not be assumed that the two forms of stimulation elicit identical responses. In addition to differences with respect to learning, such as were observed in Nakao's cats, there are other differences, for example, in attack itself. The so-called "Halloween stance" in which the cat's back is arched and its legs extended was never observed in response to tail shock. Attack elicited by stimulating the tail led to biting at any part of the rat's body that protruded, while attack due to brain stimulation was commonly directed at the rat's neck. For these reasons, the present results should not be interpreted to mean that tail shock and brain stimulation elicit identical reactions, but rather that they elicit reactions which may overlap. With respect to quiet biting attack, there is no reason at present to postulate any overlap, since there is no indication of transfer.

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Received August 9, 1965