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Amnesic effects of cooling and heating in mice¹

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Albino CF1 female mice were heated with a diathermy unit immediately following training on a single-trial passive-avoidance task. Retention, tested 24 h later, was significantly impaired only in those animals that had heat-induced convulsions. Even elevations of temperature more than 5 deg C above normal, whenever they did not produce convulsions, failed to produce amnesia. These results indicate that even the strong stimulation provided by hyperthermia is not sufficient in itself to produce amnesia.

A wide variety of posttrial treatments have been shown to influence memory in mice and rats (Jarvik, 1968; McGaugh, 1968). There are conflicting reports in the literature on the ability of cooling or heating to impair memory. Some investigators have failed to find any effect of cooling on either learning or memory in rats or hamsters (Andjus et al, 1956, in rats; Mrosovsky, 1963, in rats; Ransmeier & Gerard, 1954, in hamsters). Others have reported impairment of memory in mice by cooling or heating (Beitel & Porter, 1968; Jacobs & Sorenson, 1969; Sudak & Essman, 1962). Cerf & Otis (1957) have reported that heating goldfish after a learning trial impaired their memory, and Agranoff (1967) reported that cooling goldfish prolonged the consolidation interval. Since our version of the one-trial passive-avoidance test (Jarvik & Kopp, 1967) is sensitive to a variety of amnesic treatments [e.g., electroconvulsive shock (ECS), cycloheximide, and brain puncture], we thought it would be instructive to compare heating and cooling

with these treatments in this particular test.

SUBJECTS

Female albino mice, CF1, obtained from Carworth Farms and weighing 18-20 g, were used. They were approximately 8-9 weeks of age at the time of the experiment and were housed in groups of eight in metal cages with free access to food pellets and water.

APPARATUS AND PROCEDURE

A trough-shaped two-compartment step-through apparatus was used (Jarvik & Kopp, 1967). The mouse was placed in the outer, illuminated, smaller compartment facing a small opening to the larger, dark chamber, thereby activating a timer. When the mouse stepped into the larger, dark compartment and reached the third pair of metal plates that served as a floor, the timer stopped and a shock was delivered (800 Vac through 2 megohms in series, causing about 320 microamperes root mean square (rms) $\pm$ 20% flow for 0.8 sec). The animal usually received one and no more than three such shocks before running out into the smaller, lit compartment. This one-trial learning procedure generally took less than 20 sec.

Immediately after receiving this treatment, the mouse was removed from the step-through apparatus, and its rectal temperature was taken by means of a digital thermocouple thermometer. For heating, the animal was then placed on a table under an overturned glass jar. A diathermy unit from a Raytheon Microtherm machine, Model CMD5, was placed directly over the jar (Millichap, 1960). Treatments varied in time of exposure (90 to 180 sec) and in percentage of total power put out by the machine (30% $\pm$ 5% in the treatment group and 0% in the control group). The step-through

latencies were redetermined 24 h later with an upper limit of 300 sec.

RESULTS

Six groups of animals were tested. Groups A to C were preliminary experiments to determine if raising of body temperature to subconvulsive temperatures caused memory deficits. It also served to establish the approximate length of exposure to the diathermy apparatus that was needed to cause convulsions in some of the animals and not kill them, while, at the same time, allowing other animals to be heated to temperatures below the convulsive threshold.

Control animals are Ss that were not heated. However, in Groups D and E, in which some heated Ss convulsed, the heated Ss that failed to do so serve as a control group. They, in turn, are compared with the nonheated control group in determining the effect of subconvulsive temperature elevations on memory. Animals that died as a result of the heat treatment and thus could not be retested after 24 h (2 in Group C, 10 in Group E, and 6 in Group F) are not included in Table 1.

Inspection of the results summarized in Table 1 shows that animals that were heated but failed to convulse did not show a significant memory deficit. Those animals exhibiting tonic-clonic convulsions (labeled "yes" in Table 1) showed retrograde amnesia for the one-trial learning experience ($p < 0.01$) when compared with those labeled "none." When retested after 24 h, their latencies for entrance into the dark chamber were not significantly different from naive Ss during their first-trial learning experience. There was no significant difference between the nonconvulsing heated animals and the nonheated animals, none of whom, of course, convulsed.

The exact temperature at which convulsions occurred was difficult to determine since the rectal temperatures obtained in surviving Ss were lower than core temperatures taken on Ss that died in convulsions. This may account for the fact that one group without convulsions (Group D, 30% power) reached a median temperature of 43.6 deg C, while another group (Group C, 30% power), with convulsions, reached a median temperature of 42.5 deg C.

DISCUSSION

These experiments demonstrate that extreme changes in body temperature per se do not impair memory in our one-trial learning situation. Only when the temperature of the animals was raised sufficiently to produce a convulsion was retrograde amnesia produced.

Table 1
Effect of Diathermy Heating Upon Memory in Mice

Group	N	Duration of Diathermy Treatment (Sec)	Per Cent Power	Convulsions	Median Initial Temp. (°C)	Median End Temp. (°C)	Median Retest Latency
A	8 control	90	0	none	37	37	300+
	8	90	30	none	37	39.5	300+
B	8 control	120	0	none	36	36	274.6
	8	120	30	none	36	40	175.1
C	8 control	300	0	none	38.1	37.95	300+
	8 (2 deaths due to treatment)	exposed until convulsions (150-240 sec)	30	yes	38.15	42.5	42.5
D	8 control	180	0	none	37.85	37.85	300+
	12	180	30	none	37.8	43.6	300+
E	8 control	180	0	none	38.9	38.8	300+
	8	180	25-35	none	37.45	42.45	286.3
	4 (10 died in convulsions)	180	25-34	yes	38.2	43.1	16.4
F	8 control	180	0	none	39.15	39.5	300+
	12	180	25	none	39.05	43.1	300+
	6 (6 died in treatment)	180	25	yes	39.4	44.3	18.1

Opposite results were reported by Jacobs & Sorenson (1969), who found that immersion of mice in hot (48 deg C) or cold (1 deg C) water for 10 sec immediately following a single passive-avoidance task resulted in significant impairment of retention 24 h later. It may be that the warm tactile stimulation of Jacobs & Sorenson (1969) was more important than the uniform heating of the body by the diathermy; possibly also, the subtle differences in the two training procedures may have been responsible for the differences in results.

Jacobs & Sorenson (1969) were able to raise the body temperature of their animals by a mean increment of only 0.8 deg C when they produced an amnesic effect, whereas an increment of more than 5 deg C

in our animals (that did not convulse) had no amnesic effect.

In any case, it is clear that extreme body heating alone of mice that had been trained in our step-through task was markedly less effective than convulsions due to heat, electroconvulsive shock, cycloheximide, spreading cortical depression, and a number of other treatments.

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NOTE

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