A NEW TECHNIQUE FOR MEASURING THERMOREGULATORY BEHAVIOR IN THE RAT¹

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A tracking procedure was used to investigate the ability of rats to regulate their ambient temperature. Rats were placed in a chamber with two levers; depressions of one lever controlled a cold-water flow (11°C) and the other controlled the flow of hot water (57 ± 1°C). If it alternated responses, the rat could regulate temperature within these two extremes. With training, this regulatory behavior resulted in a narrow environmental temperature range that approximated normal body temperature.

Rats exposed to either a cold or a hot environment will attempt to maintain their normal body temperature by bar pressing for heat or cold. Carlton and Marks (1958) demonstrated that heat could be used to reinforce responding when rats were subjected to an environmental temperature of 2°C. Laties and Weiss (1960) found that the rate of such bar pressing varied with the animal's degree of acclimatization to cold, and that it was functionally related to food and pantothenic acid deficiency, thyroid activity, and parameters of heat reinforcement (Weiss, 1957; Weiss and Laties, 1960, 1961; Laties and Weiss, 1959, 1960). Rats will also increase their response rates when trained to escape heat by pressing for cold (Epstein and Milestone, 1968; Lipton, 1968).

The above studies concerned with self-regulation. The present investigation used a two-way, or a "tracking", procedure to assess the capability of rats to regulate against both hot and cold.

METHOD

Subjects

Five experimentally naive male Long-Evans rats were used. During the study there was a mechanical failure and one animal drowned in the water bath as a result of heat fatigue. At the beginning of the research the animals

were approximately 95 days old and averaged 310 g. They were maintained in an approximately 21°C room with unlimited food and water. All subjects were shaved with a clipper before each daily experimental session.

Apparatus

The general features of the experimental chamber have been schematized in Fig. 1.

The metal operant chamber was 8.26 by 10.10 by 17.18 cm and contained two air-flow switches mounted vertically from the top at one end of the chamber. The attached levers were 2.54 by 0.63 cm and required a lateral force of 0.0005 N for circuit closure. A 110-v ac double solenoid water valve, mounted on the same wall as the two levers, allowed a flow of water into the experimental chamber at the rate of six liters per minute. The operant chamber was housed in a watertight box with two overflow tubes that kept the water level at a depth of 7 cm inside the operant box.

Once a lever was pressed, cold (11°C) or hot (57 ± 1°C) water flowed into the chamber. The right lever delivered hot water, the left cold. Thus, if cold water was flowing the subject was required to press the right-hand lever, which initiated hot water and terminated the cold. Additional responses to that lever were then ineffective; a response to the left lever started the cold water flow and stopped the hot. Alternation of single responses, first to one lever and then to the other, provided a means of regulating the temperature of the water bath.

Seventy seconds were required to sweep the complete range from 11° to 57°C, representing

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Table 1

Mean temperature, standard deviation, and total number of responses per 30-minute sessions for thermoregulatory behavior by rats.

Session	1			2			3			4		
S	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.
1	33.0	13.05	49	33.5	18.65	24	34.2	11.82	73	33.9	12.17	78
3	32.5	13.50	86	32.8	13.29	88	33.5	12.86	82	32.2	12.54	68
4	34.5	11.77	82	35.6	9.21	119	35.8	6.51	127	35.6	6.37	134
11	34.1	9.67	127	33.7	12.32	91	34.1	9.71	97	34.4	9.82	99
Session	5			6			7			8		
S	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.
1	37.8	18.33	16	33.6	18.72	25	34.0	10.57	87	34.2	10.22	93
3	31.6	16.29	14	32.8	11.12	87	32.6	11.03	94	32.4	13.21	65
4	35.1	9.72	98	36.7	0.71	269	36.6	0.53	370	—	—	—
11	34.6	8.63	120	34.9	9.27	112	34.1	10.16	97	34.7	9.22	133
Session	9			10			11			12		
S	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.
1	33.8	11.92	65	38.1	4.94	212	38.2	4.53	266	—	—	—
3	33.2	11.71	82	34.1	8.76	143	33.2	6.46	108	34.7	3.48	234
4	—	—	—	—	—	—	—	—	—	—	—	—
11	34.3	8.97	115	34.1	9.27	107	35.4	7.68	168	34.9	8.37	146
Session	13			14			15			16		
S	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.
1	—	—	—	—	—	—	—	—	—	—	—	—
3	34.9	3.63	248	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—
11	35.2	7.88	126	35.3	7.71	122	36.5	6.37	244	35.5	7.82	184
Session	17			18			19			20		
S	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.	M	SD	Total Res.
1	—	—	—	—	—	—	—	—	—	—	—	—
3	—	—	—	—	—	—	—	—	—	—	—	—
4	—	—	—	—	—	—	—	—	—	—	—	—
11	36.3	6.31	220	37.5	6.58	196	36.7	0.61	326	—	—	—

an average change of approximately 1°C every 1.5 sec; within the more restricted range of 25° to 45°C, the rate of change was 1°C per sec. With both hot and cold water valves simultaneously open, the resulting blend was 36°C.

Changes in environmental temperature were read from a thermometer with its bulb 2.54 cm from the floor of the chamber. These environmental temperature changes were correlated with the responses recorded on a recording attenuator (Grason Stadler, Model E7110A).

Procedure

The subject was placed in the operant chamber with a 36°C environment at the beginning of each session. Within 30 sec, the experimenters initiated a cold-water flow that continued until a response to the right-hand lever was emitted; *i.e.*, the animal initiated the flow of hot water. A narrowing of the environmental temperature range required an alternating response pattern between the two levers. All experimental sessions lasted 30 min and were conducted at the same time each day. Crite-

Fig. 1. A schematic of the experimental chamber.

rior performance was defined as maintenance of environmental temperature within a range of 5°C for 5 min during two consecutive daily 30-min sessions. Immediately after the 30-min session of the second day at criterion, each subject was placed in a steady flow of 36°C water for 10 min.

RESULTS

Table 1 presents the individual mean temperatures and their standard deviations, as well as the total number of responses per ses-

sion. The statistics presented were based on 40 pairs of temperature measures selected at random from each session. Each pair of temperature measures consisted of a high temperature, representing that point at which the animal pressed for cold, and the following low temperature or point at which the animal pressed for hot.

The differences between mean temperatures from the first and the criterion sessions were non-significant for each animal ($p > 0.05$ by t-test); however, the mean temperature around which each animal regulated was higher in the criterion session than in the first session. Similarly, differences between mean temperatures for the animals on the criterion sessions were also non-significant ($p > 0.05$ by t-test). There were significant differences in dispersion between the first and criterion sessions for each subject ($\lambda = 1.99, 4.28, 4.23, 2.63$ $p < 0.05$, Mood's Square Rank test for Dispersion, Fryer, 1966). As a consequence, the environmental changes increased between the first and criterion sessions. During the 10-min post-criterion interval, in which the water temperature was 36°C , no responses were emitted by any subject.

Fig. 2. Changes in environmental temperature for Subjects 4 and 11 as a function of differential responding on the initial and criterion 30-min sessions.

Figure 2 illustrates the change in regulatory behavior between the initial and criterion 30-min sessions for Subjects 4 and 11. Subject 4's record had the least variability with the fewest days to criterion, indicating the highest rate of change. Subject 11's record had the most variability, required the greatest number of days to reach criterion, and exhibited the lowest rate of change.

DISCUSSION

These findings indicate that the variability of the environmental temperature was reduced with increased number of responses and the mean ambient temperature did not fluctuate significantly during this transition. It is evident from these data that rats learn to limit their environmental temperature to a range of 5°C or less, which encompasses normal body temperature. This conclusion is strongly supported by the fact that no responses were emitted by any animal during the 10-min post-criterion period. These results support Hardy's (1965) contention that a homothermic organism has some preference level or range that it attempts to maintain. When such an organism is displaced from that range by environmental changes, it will learn to regulate against displacement if given the opportunity.

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