THE DEVELOPMENT AND THE EXTINCTION OF HYPERTHERMIA INDUCED BY CONDITIONED AVOIDANCE BEHAVIOR IN RATS¹

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Hyperthermia was observed at the end of each conditioning session in rats trained to avoid electric shocks by jumping on a platform. The temperature rise was also observed after the conditioned behavioral response was well established and was elicited even in the absence of shocks. There was no tendency for the hyperthermia to diminish over the course of nine extinction sessions.

Recent investigations in this laboratory have shown that rats subjected to a classical fear-conditioning procedure react to every experimental session with a considerable temperature rise. The hyperthermic reaction was considered to be a somatic response to a stress situation and a measurable sign of fear.

On the other hand, conditioned fear-motivated operant behavior in animals is almost generally accepted as a model of anxiety (Estes and Skinner, 1941; Brady, 1956; Maffei, 1959; Kinnard, Aceto, and Buckley, 1962). Therefore, it was of interest to investigate temperature changes in rats submitted to an avoidance procedure.

Material and Method

Experimental animals were male albino rats, Wistar strain, weighing 130 to 150 g at the beginning of the study.

A one-compartment test apparatus with an electrifiable grid floor, small lamp bulb mounted on the wall and a removable platform 6.75 by 0.75 by 2.25 in. (17 by 2 by 6 cm) was employed. The platform was manually presented to the rats at regular time intervals through a slit in the compartment door. Electric shock and light presentation were controlled automatically.

A total of 40 rats (Ss-T), divided in groups of five, were subjected to weekday training. The training schedule consisted of 20 trials, each trial lasting for 30 sec. Electric shocks (the unconditioned stimulus, US) were preceded by a 5-sec warning signal (light and platform presentation as the conditioned stimulus, CS) during which the subjects should jump on the platform. Failures resulted in a 5-sec electric shock. Before starting the next trial, an additional 10-sec rest interval was given.

Fifteen Ss-T were individually matched and paired with other 15 rats (Ss-I). The latter were subjected to the same experimental procedure throughout and received the same number of electric shocks as did the corresponding Ss-T but the possibility of avoidance or escape was never presented.

Two other control groups (Ss-C), each consisting of five rats, were placed in the lighted test compartment for 15 min each day, but no other stimuli were given.

After the avoidance response had been established, different groups of rats were subjected to different extinction procedures. For five rats selected at random from the matched Ss-T group, extinction sessions were identical to the acquisition sessions except that the shocks were omitted. For the second extinction group (10 rats) extinction sessions consisted of regular platform presentation but both light (CS) and shocks (US) were withheld. Both groups were given nine extinction sessions, each one consisting of 20 trials.

A single extinction session of 15-min duration with *all* US and CS (even platform presentation) omitted was given to another group of 15 trained rats.

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Table 1

The hyperthermic response of rats subjected to escapable and inescapable shocks after the first conditioning session.

Group of rats	Number of rats	Temperature		Temperature rise $\Delta t^{\circ}\text{C} \pm \text{SEM}$
		before conditioning	after session	
Ss-T	20	37.50	39.12*	1.62 ± 0.20
Ss-I	15	37.40	38.93*	1.53 ± 0.30
Controls	10	37.62	38.20	0.58 ± 0.25

* $p \leq 0.05$ in comparison to the controls
Ss-T: trained rats
Ss-I: rats subjected to inescapable shocks

All subjects were kept in standard Plexiglas cages in an air-conditioned laboratory room ($T = 24 \pm 1^{\circ}\text{C}$) with food and water freely available except during the test performance. The temperature in the test compartment was permanently controlled and never exceeded $\pm 1^{\circ}\text{C}$ of the room temperature. The rectal temperature was measured by means of an electric thermometer immediately before and after each test session. Statistical evaluation of the results was performed according to the student's t-test.

RESULTS

In all animals subjected to shocks, a temperature rise was observed at the end of every training session. Table 1 shows the results for the first session.

No significant difference was observed between temperature rise of rats that could avoid shocks and those subjected to inescapable shocks, but both groups differed significantly from controls ($p \leq 0.05$). Control animals reacted to the unusual environment of the test chamber with a slight increase in temperature which was, however, within normal limits. With few exceptions, the subjects allowed to avoid shocks learned to jump on the platform in the course of 10 sessions. Further training usually did not increase the performance. The more proficient avoidance behavior resulted in rapidly falling shock frequency, as shown in Fig. 1.

An analysis of variance was computed over the acquisition period in order to determine whether the cumulative number of shocks each individual subject received could be respons-

Fig. 1. The hyperthermic response of rats during the acquisition of avoidance behavior. The hyperthermic response of trained subjects during the acquisition of avoidance behavior is presented in comparison to the temperature rise of subjects subjected to inescapable shocks and to that of control animals. Each vertical bar represents the average $\pm$ S.E.M. of five rats selected at random. The temperature recorded in the test chamber was $24 \pm 1^{\circ}\text{C}$.

Fig. 2. The conditioned hyperthermia in rats during the extinction period (only shocks omitted). Each vertical bar represents the average values $\pm$ S.E.M. of five animals. The controls are for comparison only since their treatment did not vary.

ible for the temperature rise. The results showed no correlation between the number of shocks given and the temperature rise, at any time tested.

The hyperthermic reaction observed in subjects during the acquisition of avoidance behavior was maintained after the conditioned jump response was well established. Even the interruption of training for more than three

days did not influence either the behavioral response or temperature reaction. Both behavioral and hyperthermic response were found to be resistant to extinction when shocks were omitted.

Figure 2 illustrates the persistence of hyperthermia in trained animals under such conditions. In all extinction sessions, the temperature was significantly higher (to $p \leq 0.01$

Fig. 3. The trend with time for conditioned hyperthermia in trained rats. Individual temperature changes (Δt) are plotted over time and the analysis of variance was computed. There is no significant trend with time for the temperature rise to change. The arrow indicates the beginning of the extinction period.

Fig. 4. Extinction of avoidance response and hyperthermia in trained rats. (light and shocks omitted). The arrow indicates the last preceding normal training session. Each vertical bar represents average values $\pm$ S.E.M. of 10 animals. Compared to the controls, the temperature rise is significant to $p \leq 0.05$ level.

level) than the temperature of the controls and in Sessions I and VIII significantly higher (at $p \leq 0.05$ level) than the temperature of the paired Ss-I (inescapable). The temperature rise of individual animals plotted over the training as well as extinction period (analysis of variance) showed no tendency for the temperature rise to extinguish with time (see Fig. 3). Avoidance responding was maintained without exception at the 100% level.

In the paired Ss-I group, the temperature declined closer to that of the controls. The difference in the temperature rise of the Ss-I and Ss-T was small ($p \leq 0.1$) in all sessions except I and VIII (see above). A particularly low basal temperature, for which no adequate

explanation was found, was observed in this group only during the extinction period.

The patterns of behavioral and somatic response were found to differ when both US and CS (light) were omitted during the extinction period. Despite regular platform presentation, the behavioral response rapidly extinguished and after seven sessions all rats failed to jump. In contrast, the temperature still persisted, although at a slightly lower level (see Fig. 4).

The differences between the temperature rise observed in normal training sessions and the temperature rise during the extinction sessions was not statistically significant.

Table 2 shows that, in a single extinction

Table 2
The Hyperthermic Reaction of Rats after One Normal Training Session and One Extinction Session

Group of rats	Number of rats	Normal training session**			Extinction session*		
		initial	after	Δt °C $\pm$ SEM	initial	after	Δt °C $\pm$ SEM
Ss-T	15	37.47	38.88	1.41 ± 0.37	37.26	38.81	1.55 ± 0.38
Ss-I	15	37.40	38.72	1.32 ± 0.27	37.10	38.34	1.24 ± 0.33
Controls	5	37.48	37.72	0.24 ± 0.18			

*All unconditioned and conditioned stimuli were removed and the platform was not presented.

**The training session is arbitrarily selected.

session with both US and CS, as well as platform presentation withheld, the subjects reacted with the same temperature rise as in the normal training sessions.

The temperature of the control animals (Ss-C) fluctuated periodically but was always within normal limits.

DISCUSSION

Many autonomic reactions have been described in experimental animals subjected to stress; *e.g.*, hyperglycemia (Jakoubek and Gutmann, 1960), hypertension (Aceto, *et al.* 1963) and heart rate acceleration (Cohen and Pitts, 1968). Conditioned antidiuretic response was also observed in dogs subjected to a chronic stress situation (Corson 1966).

Hyperthermia induced by conditioned avoidance behavior was observed by Boff and Scheckel, (1964). However, their study was not systematically devoted to this problem and the development and the persistence of conditioned hyperthermia were not described. Similarly, it was not clear if the increased motor activity of rats responding on their modified Sidman avoidance schedule could have been responsible for the temperature rise.

Many factors could account for the observed phenomenon; muscular activity, conditioning process, applied shocks, and even manual handling and placing in an unusual environment could induce considerable physiological changes.

It is difficult to assess the role of motor activity in the production of hyperthermia. In the present experiments there is, however, a lack of correlation between the extinction of avoidance response and temperature in the second extinction group. Also, during the single extinction trial, gross motor activity was not observed but the temperature still rose. Furthermore, the Ss-I, which were not required to perform to avoid shocks, also reacted to the conditioning situation with hyperthermia. These animals were in no instance more active than Ss-T as judged by visual observation. The possibility still remains that an unobservable muscular activity was present.

A direct effect of shock application could be ruled out by the fact that statistical analysis failed to show a correlation between the cumulative number of applied shocks and temperature response. It is also possible to exclude

manual handling or environmental changes because, in control animals (Ss-C), hyperthermia was not observed even after the first experimental session, which was presumably the more stressful one.

Another question deserves discussion. It seems conceivable that after the establishment of the avoidance behavior the amount of fear will decrease and extinguish in the course of time. McAllister and McAllister (1968) have shown that forgetting of fear, measured by learning of a new response, occurred in two days. Campbell and Campbell (1962), investigating the retention and extinction of learned fear, demonstrated its rapid and almost complete extinction after four sessions. Investigations of metabolic reactions due to fear have shown that as soon as the rats learned to avoid shocks in a shuttlebox, the hyperglycemia observed during the learning period disappeared (Hilton and Vrbova, cited by Corson, 1966). Similar observations were reported by Jakoubek and Gutmann (1960). In a recent study on catecholamine release during classical conditioning in monkeys, Ferreira, Gollub, and Vane (1969) observed a complete extinction of epinephrine release, heart rate, and blood pressure changes after 11 trials in which only the conditioned stimulus was presented.

In view of these findings it is peculiar that the temperature rise observed in the present studies did not extinguish even in the absence of conditioned light stimulus, whereas the avoidance response did. Such a dissociation between behavioral and physiological response cannot be readily explained. It could be only supposed that the temperature rise represents a very sensitive indicator of fear that is elicited not by a single conditioning stimulus but by a "compound" stimulus (McAllister and McAllister 1962) so that the presence of one component may be sufficient to produce the conditioned physiological reaction.

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