The discrimination of differences in duration of a thermal reinforcement¹

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Rats trained to barpress for a blast of cold air in a hot environment can discriminate changes in duration of the reinforcement by modifying their rate of obtaining reinforcement. The discrimination is observed to be (1) dependent on the direction of the change and (2) proportional to the base duration. The difference limen (DL) is also found to be direction dependent. The possibility that the results reflect a response to changes in the aversiveness of the "reinforcement" is considered.

Recent investigations on behavioral thermoregulation have demonstrated that rats can discriminate changes in the magnitude of the reinforcement when trained to depress a lever for a heat reinforcement in a cold environment (Weiss & Laties, 1961; Carlisle, 1966) or a cold reinforcement in a hot environment (Kristt & Sechzer, 1969). In a cold environment the Ss can discriminate changes in intensity of the reinforcement as well as changes in its duration. The modifications in response rate vary inversely with a change in magnitude of the reinforcement.

At high environmental temperatures we have found that rats can similarly discriminate differences in intensity of the cold reinforcer; the colder the reinforcement, i.e., the greater the intensity, the lower the rate of obtaining reinforcement. In this report we will study the manner in which rats in a hot environment discriminate differences in the duration of a burst of reinforcing cool air.

METHOD

The Ss were four male Sprague-Dawley rats. They were stabilized at 325 ± 5 g for 4 weeks prior to the experiment as well as during its course. Water was available on a

schedule of 50 ml every 12 h. All Ss were individually housed in metal cages. The ambient temperature was $24 \pm 2^\circ\text{C}$. During the experiment, each S was run at approximately the same time of day to allow for possible effects of the diurnal adrenal cycle. Prior to the present study, all Ss had been trained to a stable performance level.

The training and testing apparatus consisted of a modified Skinner box, placed within an environmental chamber, the temperature of which was stable to $\pm 2^\circ\text{C}$. When the S depressed the lever, a single reinforcing burst of $24 \pm 2^\circ\text{C}$ air was delivered onto the perforated front face of the Skinner box above the lever (Kristt & Sechzer³). All training and testing was carried out at a 37°C environmental temperature with duration of reinforcement at 5.0 sec.

The actual experiment was composed of six 3-h sessions per S. The duration of reinforcement varied between 2.5, 5.0, 7.5, and 10.0 sec. Each 3-h session was divided

Table 1
Summary of Conditions Under Which Experiment was Performed. Each condition represents a separate 3-h session. Each entry in the Table represents the particular reinforcement duration used in the corresponding h.

Condition	Hour 1 (sec)	Hour 2 (sec)	Hour 3 (sec)
1	5	2.5	5
2	5	7.5	5
3	5	10	5
4	10	5	10
5	2.5	10	2.5
Control	5	5	5

into three 1-h parts. The design of the six sessions is shown in Table 1. Ordering of the conditions, 1, 2, 3, and control was randomized for each S.

RESULTS

Figure 1 summarizes the data and represents the mean pattern for the S group as a whole in each of the respective conditions. It can be seen that increases in

Fig. 1. Summary of the pattern for all Ss in each of the experimental conditions (Table 1). The dotted line in Condition 2 was added to emphasize that the change in rate of reinforcement does not change substantially over that seen in the control session. Each point represents the mean number of reinforcements obtained in each session hour.

Fig. 2. Histogram A compares the mean change in reinforcement rate (ΔRF) in each of the larger limbs in the curves in Fig. 1, Conditions 1, 2, 3, and control. Histogram B compares the mean change in reinforcement rate in the smaller limbs. The ordinate identifies the limb and indicates the direction of the change by a small arrow. Four reinforcements have been subtracted from all entries as a correction for the mean ΔRF of +4 in the control (5 sec).

the duration of reinforcement result in decreases in rate of response compared to the 5.0-sec base duration; decreases in duration of reinforcement result in increases in rate of response. The unequal magnitudes of the two limbs in each of the experimental curves, except the control, should be noted. This observation was originally made on the data from Conditions 1, 2, and 3. Conditions 4 and 5 were added in order to reduce the possibility that this pattern merely represented a procedural artifact. Since this pattern also appears in both of the last two conditions in a predictable fashion we concluded that this was an actual phenomenon.

In Fig. 2A the magnitudes of the larger limbs, i.e., the larger change in rate of reinforcement between two consecutive hours in a particular condition, have been plotted; the magnitudes of the smaller limbs are plotted in Fig. 2B. It can be seen that the larger change in rate of reinforcement is always associated with a change from a reinforcement of a longer duration to one of shorter duration. Hence the discriminative response to a change in duration appears to be a relative one depending not on the actual magnitude of the reinforcement in a particular condition, but on the order of presentation or direction of the change.

Moreover, it appears that it is not an absolute difference in duration that is discriminated but a proportional one. This can be readily seen in Fig. 2B. The increment of 2.5 sec is well discriminated when the reinforcement changes from a

2.5-sec to a 5.0-sec duration, but not when the reinforcement changes from 5.0 sec to 7.5 sec. This suggests that the DL (difference limen), or threshold, for a duration increment is around $3/2$ or $2/3$ of the base duration of 5 sec, since an increment of $2X$ or $1/2$ base is well discriminated. Contrariwise, Fig. 2A indicates that a decrement of 2.5 sec, when the duration of the reinforcement is 7.5 sec, is easily discriminated. This suggests that a decrement in duration may be associated with a lower DL, i.e., the DL is also direction dependent.

The data, then, suggest that a discrimination of differences in duration of a thermal reinforcement at high environmental temperatures occurs in the following manner:

When

$$\frac{D_0 - D_1}{|D_0 - D_1|} = +1$$

then

$$\begin{aligned} \Delta RF &= k \\ DL &< 3/2 B \text{ for } D > 5 \text{ sec} \\ (DL > 2/3 B \text{ for } D < 5 \text{ sec}) \end{aligned}$$

but when

$$\frac{D_0 - D_1}{|D_0 - D_1|} = -1$$

then

$$\begin{aligned} \Delta RF &< k \\ DL &\geq 3/2 B \text{ for } D > 5 \text{ sec} \\ (DL \leq 2/3 B \text{ for } D < 5 \text{ sec}) \end{aligned}$$

where ΔRF is the change in rate of reinforcement as a result of a change in duration of the reinforcement, with respect to the base duration, viz, 5 sec; k is some constant magnitude; B is the base duration; D is a duration other than the base; $D_0 - D_1$ is the difference in duration between any two consecutive hours in an experimental condition; DL is the difference limen. (The parentheses indicate that the statement is merely a prediction.)

Finally, we should note that the reinforcement rate observed in the hour in which the reinforcement duration was 2.5 sec or 10 sec is not an artifact of the experimental design. This can be seen from Fig. 3. The curve marked Hr-1 was made from values for the reinforcement rates at 2.5 and 10 sec taken from Hour-1 values in Conditions 5 and 4, respectively. In the curve marked Hr-2, the values for the reinforcement rates at 2.5 and 10 sec are taken from Hour 2 of Conditions 1 and 3.

Fig. 3. Comparison of the rates of reinforcement at different durations of the reinforcement. The curve labeled Hr-1 represents the reinforcement rate for Hour 1 in Conditions 4, 5, and control; Hr-2 represents the reinforcement rate for Hour 2 in Conditions 1, 3, and control (Fig. 1).

Figure 3 suggests that the reinforcement rates at these two durations of reinforcement are not affected by experimental order.

DISCUSSION

The most substantial problem in interpreting these results is raised by the observation that naive rats find a stream of air directed at their heads aversive. Hence, even though it is tempting to explain the data by suggesting the existence of an inverse relationship between the duration of a cooling air burst and the rate of reinforcement (i.e., that the behavior has thermoregulatory significance), we are forced to consider a second possibility. The alternative would be that there is an inverse relation between aversiveness and rate, i.e., as the duration increases the aversiveness of the air burst also increases and the reinforcement rate drops. Moreover, the work by Crespi (1942, 1944) and Zeaman (1949) strengthens this latter point of view. In their experiments, an increased incentive led to an increased performance. On the basis of these findings by Crespi and Zeaman, then, the increase in duration of the reinforcement must involve a decreased incentive. Furthermore, in Karsh's study (1963) on the interaction between punishment and reward, Ss are trained in a situation in which they receive mild shock on obtaining a food reinforcement. These Ss exhibit a decrease in performance when the intensity of the shock increases and an increase in performance when the intensity of the shock decreases. Karsh, however, does not observe a differential discrimination of change in intensity that is related to the direction of change as we have noted above (Fig. 2). This difference between Karsh's

findings and our own may be critical for our hypothesis that the patterns seen in Fig. 1 are thermoregulatory and do not represent avoidance-like responses. For, in thermoregulatory terms, it is reasonable to expect that a S would react more vigorously to a situation in which cooling per reinforcement decreases—a potentially lethal circumstance—than to one in which cooling increases per reinforcement. Also, during the hour of 10-sec reinforcement, reinforcement rate could have dropped to 1/2 base without compromising thermostasis, yet the Ss continued to perform at much higher levels. This implies, contrary to the above, that the 10-sec reinforcement does provide a greater incentive. Finally, it should be mentioned that several investigations on behavioral thermoregulation in a cold environment (Baldwin & Ingram, 1967; Weiss & Laties, 1960, 1961; Carlisle, 1966) have demonstrated that, within a thermoregulatory context, an increase in magnitude of reinforcement is associated with a decrease in performance. This suggests that the analysis of

thermoregulatory incentive on the basis of the work by Crespi and Zeaman may not be entirely adequate. For instance, in our experiments on thermoregulation in a hot environment “cessation” of work decreases muscular thermogenesis and, hence, may be reinforcing in itself.

Lastly, we should note that the existence of a difference threshold proportional to the base duration may be the basis for a behavioral thermoregulatory version of Weber’s law.

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NOTES

1. This research was supported by Muchlstein Fellowship Fund Grant No. 8-1010-576.
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3. Kristt, D. A., & Sechzer, J. A. Patterns of behavioral thermoregulation at high environmental temperatures in rats. In preparation.

(Accepted for publication October 22, 1969.)