reinforcement. Additionally, the runway studies and the reinforcement-omission studies differ from the present study in that reinforcement frequency (as measured by number of reinforcements per session in each schedule component) underwent a change. No change in reinforcements per session occurred in the present experiment.

It should be noted that the procedure used is identical in many respects to procedures used to establish a stimulus as a conditioned reinforcer (Kelleher & Gollub, 1962). Following Schuster's (1969) assumption, when two identical food schedules are in effect, the addition of a schedule of conditioned reinforcers conjointly to one schedule should increase the "reinforcement value" of responding on that schedule and consequently produce a rate difference between the two food schedules. Although Schuster's failure to find a contrast effect is perhaps explained by the rate requirement in effect for the schedule of conditioned reinforcement, the increase in response rates in the present experiment do not seem to be predictable on the basis of conditioned-reinforcement theory alone. Instead, the "reinforcing value" of the schedule in the signaled component seems to have been diminished, rather than enhanced, by the addition of the unreinforced signals.

The effect produced by reducing the probability of signaled reinforcement in this way seems to resemble more the effect obtained by Brethower & Reynolds (1962) when a mild electric shock was added to one component. The results of their experiment along with the present results seem to be in line with Bloomfield's (1969) assertion that the occurrence of contrast in multiple schedules is in some sense a result of a "change for the worse" in one component. Among the class of events suggested by Bloomfield as a "worsening of conditions" are reduction in reinforcement frequency, the introduction of punishment, and restraint involved in the development of inhibition. Interpreted in these terms, the present results simply specify an additional condition in which an increase in responding occurs in a schedule component where such an increase is "uncalled for" by the contingencies.

A suggested alternative explanation for these data is the following: To the extent that one may still think of signaled VI as maintaining the essential characteristics of a variable-interval schedule of reinforcement, it would seem equally correct to think of the unreinforced signal presentations as a schedule of signaled extinction. Thus, it is possible to consider the condition in which the probability of signaled reinforcement is .50 as a mixed schedule composed of signaled VI and signaled extinction. Considered in this way, the transition in the signaled component from signaled VI 2 min to *mix* (signaled VI 2 min, signaled extinction) represents a decrease in the reinforcement "value" of responding in the signaled component. That animals prefer multiple to mixed schedules of reinforcement, when both provide the same rate of food reinforcement, is well documented (Bower, McLean, & Meacham, 1966) and lends support to the present interpretation of these results. Experiments are currently under way to determine if a gradation of these effects occurs over a wider range of probability values. The procedure is clearly a useful and promising one for investigating topics in each of the areas discussed.

REFERENCES

AMSEL, A. The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 1958, 55, 102-119.

BLOOMFIELD, T. M. Frustration, preference, and behavioural contrast. Quarterly Journal of Experimental Psychology, 1967, 19, 166-169.

BLOOMFIELD, T. M. Behavioural contrast and the peak shift. In R. M. Gilbert and N. S. Sutherland (Eds.), *Animal discrimination learning*. New York: Academic Press, 1969. Pp. 000-000.

BOWER, G., McLEAN, J., & MEACHAM, J. Value of knowing when reinforcement is due. Journal of Comparative & Physiological Psychology, 1966, 62, 184-192.

BRETHOWER, D. M., & REYNOLDS, G. S. A facilitative effect of punishment on unpunished behavior. Journal of the Experimental Analysis of Behavior, 1962, 5, 191-199.

BROWNSTEIN, A. J., & HUGHES, R. G. The role of response suppression in behavioral contrast: Signaled reinforcement. Psychonomic Science, 1970, 18, 50-52.

FERSTER, C. B., & SKINNER, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

HUGHES, R. G. The effects of signaled reinforcement in multiple schedules of reinforcement. Unpublished Master's thesis, University of North Carolina at Greensboro, 1970.

KELLEHER, R. T., & GOLLUB, L. R. A review of positive conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 543-597.

LANDER, D. G., & IRWIN, R. J. Multiple schedules: Effects of the distribution of reinforcements between components on the distribution of responses between components. Journal of the Experimental Analysis of Behavior, 1968, 11, 517-524.

REYNOLDS, G. S. Behavioral contrast. Journal of the Experimental Analysis of Behavior, 1961, 4, 57-71.

SCHUSTER, R. H. A functional analysis of conditioned reinforcement. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Ill: Dorsey, 1969. Pp. 000-000.

SIDMAN, M. *Tactics of scientific research*. New York: Basic Books, 1960.

STADDON, J. E. R., & INNIS, N. K. An effect analogous to "frustration" on interval reinforcement schedules. Psychonomic Science, 1966, 4, 287-288.

*Research conducted at the University of Maryland. Supported by USPHS Grant No. MH-01604-13 from the National Institute of Mental Health to the University of Maryland.

Avoidance of thermal stimuli in the rat

T. JAMES MATTHEWS*, LAWRENCE P. MORIN†, and RUSSELL M. CHURCH
Brown University, Providence, R.I. 02912

The study of thermally motivated instrumental behavior was extended to the avoidance-conditioning paradigm. Six Ss were trained on a thermal Sidman avoidance schedule. The UCS temperature and the ambient temperature were varied, while the temporal properties of the schedule were held constant. The results indicated that whenever the difference between the two thermal conditions is sufficient to sustain responding, the probability of an avoidance response is related to the mean of the UCS and ambient temperatures.

In the investigation of the thermally motivated instrumental behavior of the rat, there has been a consistent concern with an instrumental response that immediately improves the thermal condition of the animal (Carlton & Marks, 1958; Weiss & Laties, 1960; Carlisle, 1969). The usual procedure requires the S to press a bar to escape from a stressful drive condition into a stress-reducing reinforcement condition. This procedure has been accepted as the elementary paradigm of behavioral thermoregulation. Another way in which animals may thermoregulate is by avoiding stressful conditions. The present study is designed to study thermally motivated avoidance behavior.

There are two important differences between the avoidance and escape procedures. In the avoidance procedure, the instrumental response occurs in the presence of the less severe of the two thermal conditions, and does not produce an immediate change in temperature.

In the escape procedure the influence of the more-severe thermal condition (drive) and the less-severe thermal condition (reinforcer) have been given thorough parametric analysis (Matthews, in press). The present study provides an analysis of the comparable parameters in the avoidance paradigm. Those variables are the temperature of the more-severe stimulus (UCS) and of the less-severe

*Please send requests for reprints to the senior author at the Department of Psychology, New York University, University Heights, New York, New York 10453.

†Now at Rutgers University, Newark, New Jersey 07102.

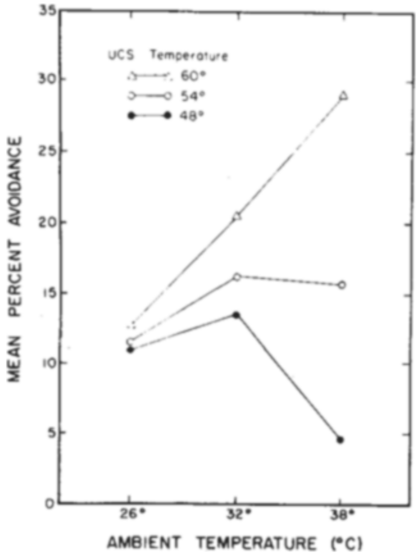

Fig. 1. Mean percentage of UCSs avoided as a function of the ambient temperature and the UCS temperature.

stimulus (ambient).

SUBJECTS

The Ss were six naive male albino Norway rats from a hysterectomy-derived barrier-sustained stock (Charles River CD). At the beginning of the experiment, their weight was approximately 200 g, and Ss were kept shaved throughout the experiment.

APPARATUS

The test chamber was an acrylic cylinder (.216-m inside diam) connected to the air inlet tube by a conical ceiling that was designed to minimize air turbulence. The floor was constructed from .016-m mesh plastic screen. A .051 x .025 x .006 m plastic bar was attached to the arm of a microswitch which was inserted through the wall of the chamber, .025 m above the floor.

A convective thermal controller (CTC) was used to control and present the thermal stimuli. It has been described in detail elsewhere (Matthews, 1969). The CTC is essentially a forced convection system that bathes the animal in air of a controlled temperature.

Air recirculates in two independent systems at independently controlled temperatures. Four-way valves select which of the two systems flows through the test chamber and which flows through a shunt. The valves switch the systems in less than 1 sec.

The air temperatures of the two systems are controlled by YSI Model 74 thermostats. In each system the air is heated by a thermostatically controlled Nichrome wire electric heating coil. Air is cooled by a thermostatically controlled pump, which forces a cold-water antifreeze solution through a heat exchanger (copper tubing surrounded by thin aluminum fins). The air is impelled through each system by .0467-m^3/sec squirrel-cage blowers. The velocity of the wind in the chamber is approximately 7.62 m/sec, and the temperature is controlled within ±0.5°C.

PROCEDURE

A modified Sidman avoidance schedule was used. The UCS was a 5-sec exposure to the more severe of the two thermal test conditions. If no responding occurred, the UCSs occurred every 5 sec. Every response in the absence of a UCS delayed the onset of the next UCS by 15 sec from the moment of the response. Responses during the UCS were ineffective.

The Ss received eight 30-min training sessions. For the first four sessions, the UCS temperature was 54°C and the ambient temperature was 38°C. The UCS temperature was increased to 60°C on the last 4 training days.

In nine 30-min test sessions, each S was exposed to all possible combinations of three UCS temperatures (60°, 54°, and 48°C) and three ambient temperatures (38°, 32°, and 26°C). The order of presentation of treatment combinations was randomized for each S. Each S was tested once on each test day.

RESULTS AND DISCUSSION

The present experiment shows that rats can learn to perform an instrumental response to avoid a thermal stress. The effect of ambient temperature and UCS temperature on the mean percentage of UCSs that were avoided is shown in Fig. 1. (The first 15 min of each test session were excluded from formal analysis, since the sessions often began with a period of nonresponding.) The percentage of avoidance responses increased as the UCS temperature increased ($F = 28.0$, $df = 2/10$, $p < .01$), and there was an interaction between the ambient temperature and the UCS temperature ($F = 3.2$, $df = 4/20$, $p < .05$). An analysis of simple effects (Winer, 1962) indicated that the percentage of avoidance responses increased as the ambient temperature increased only when the UCS temperature was at its highest level ($F = 4.9$, $df = 2/10$, $p < .05$), and that the percentage of avoidance responses increased as UCS temperature increased only when the ambient temperature was at its highest level ($F = 42.7$, $df = 2/10$, $p < .01$).

These results indicate that the instrumental avoidance response is influenced by the ambient temperature and by the UCS temperature. Although it might have been expected that the percentage of avoidance responses would increase as the difference in the temperature between the UCS and ambient conditions increased, this was not the case. The correlation between the avoidance rate and the absolute difference between the temperature conditions was −.03. The correlation between avoidance and the mean of the two thermal conditions was substantially higher ($r = +.71$, $p < .02$). Whenever the difference between the two thermal conditions is sufficient to sustain responding, the probability of an avoidance appears to be dependent upon the combined thermal effects of the two temperatures.

In order to compare instrumental behavior in the escape and avoidance situations, it is necessary to derive a measure of response strength that is not based on the procedure used to train the response. Such a measure is provided by calculating the total amount of time that the Ss remain exposed to the more stressful thermal condition in the two paradigms. The present results indicate that the thermoregulatory efficiency of rats in avoidance may not be worse than that of rate in escape training. For example, Matthews (in press) described the behavior of six rats that could escape from a drive temperature of 48°C to a reinforcement temperature of 32°C for a duration of 15 sec. The escape latencies were such that the more stressful condition remained on during 37% of the session. The comparable avoidance condition in the present experiment was one in which the rat could avoid a UCS temperature of 47°C for 15 sec by responding in the presence of an ambient temperature of 32°C. The avoidance responses were such that the more stressful condition remained on during 43% of the session. This difference of 6% did not approach statistical significance. This result suggests that rats will maintain similar levels of stress, despite major differences in the contingency between instrumental behavior and thermal stimuli.

REFERENCES

CARLISLE, H. J. Heat intake and hypothalamic temperature during behavioral temperature regulation. Journal of Comparative & Physiological Psychology, 1966, 61, 388-397.

CARLTON, P. L., & MARKS, R. A. Cold exposure and heat reinforced operant behavior. Science, 1958, 128, 1344.

MATTHEWS, T. J. A convective thermal controller for behavioral experiments. Behavior Research Methods & Instrumentation, 1969, 1, 126-128.

MATTHEWS, T. J. Thermal motivation in the rat. Journal of Comparative & Physiological Psychology, in press.

WEISS, B., & LATIES, V. G. Magnitude of reinforcement as a variable in thermoregulatory behavior. Journal of Comparative & Physiological Psychology, 1960, 53, 603-608.

WINER, B. J. *Statistical principles in experimental design.* New York: McGraw-Hill, 1962.