An incentive effect in thermally motivated behavior*

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Three shaved adult male albino rats were trained to press a lever to replace a hot air drive condition (50°C) with either a small reinforcer (32°C) or a large reinforcer (14°C). Following the 10-sec reinforcer, the drive condition was either reinstated immediately (no delay) or after a 15-sec exposure to the drive temperature, during which the bar was withdrawn (delay). Response rate during the no-delay procedure was faster for the small reinforcer than for the large. This relation reversed during the delay procedure. The former observation is similar to a satiation effect and the latter resembles an incentive effect.

The effects of thermal stimuli on instrumental behavior have been investigated primarily by students of physiological regulatory systems. Consequently, many traditional questions about the behavioral properties of motivational events have not been asked about thermal stimuli. The present work determines the role of "incentive" in thermally motivated behavior. Incentive is usually identified as an increase in response strength associated with an increase in reinforcement magnitude (Crespi, 1942; Zeaman, 1949; Guttman, 1953).

In the thermal equivalent of the reinforcement procedure, a rat is trained to press a bar to terminate a stressful "drive" condition and replace it with a stress-reducing "reinforcer." The reinforcer is terminated automatically and replaced by the drive condition for the next trial. The drive and reinforcer are defined here as stimulus values and not as intervening variables such as thermal stress. Although it might seem that thermal stress could be quantitatively defined as the internal temperature of the animal, it is lamentably true that internal temperature is actually a temperature gradient. A temperature drop of 5°C occurs between the core, which is relatively invariant, and the skin, which is strongly affected by both air temperature and vasotone. The formulation of an internal index of stress requires a greater understanding of the physiology of heat transport than is currently available. For present purposes, it will suffice to specify treatments in terms of air temperature and assume that thermal stress is some function of air temperature.

The motivational parameters of the thermal reinforcement procedure have been studied with unusually reliable results. As the intensity of either a hot or cold drive stimulus is increased, response rate

increases (Carlisle, 1966; Thorpe & Corbit, 1968; Kristt & Sechzer, 1969; Epstein & Milestone, 1968; Matthews, 1971). The reinforcer magnitude parameters (duration and intensity) have an opposite effect on behavior; as the magnitude of the reinforcer increases, response rate decreases (Weiss & Laties, 1960; Carlisle, 1966; Thorpe & Corbit, 1968; Kristt & Sechzer, 1969; Matthews, 1971).

The reinforcer magnitude effect appears to be inconsistent with the usual incentive effect of food reinforcement magnitude. Guttman (1953) demonstrated the incentive effect with an appetitive reinforcer. As the concentration of sucrose in a constant-volume liquid reinforcer was increased, response rate increased. However, these procedures for determining food and thermal reinforcement magnitude effect may not be precisely analogous. In Guttman's experiment, hunger was held constant; deprivation procedures were identical for all reinforcer magnitudes, and it was assumed that drinking during the test did not substantially reduce hunger. However, in the temperature experiment it cannot be assumed that the stress level remained constant regardless of reinforcer magnitude. Indeed, the thermoregulatory account of thermal reinforcement magnitude effects suggests that Ss respond slower for larger reinforcers because they produce a larger reduction in stress. A more appropriate food reinforcement analog to the thermal reinforcement magnitude experiment would be one which allowed hunger stress to be affected by reinforcement magnitude.

Collier (1972) reported a "free feeding" experiment in which undeprived rats were trained to press a bar for food pellets. The bar was located in the home cage and Ss could press for food at any time of day. On separate blocks of days, three pellet sizes were presented. In good correspondence with the thermal result, response rate decreased as pellet size increased. This is the familiar "satiation effect;" larger pellets more quickly reduced hunger, which in turn reduced responding.

It is likely that the operation which accounts for the difference between the Guttman incentive result and the

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Fig. 1. Summary data for each S. Dark circles indicate the response rate for the large and small reinforcers in the no-delay condition for each S. Open circles represent the delay conditions.

Collier satiation result is that in the Guttman experiment hunger was held constant. It follows that in order to demonstrate a thermal incentive effect, the thermal satiety experiment must be modified to hold stress constant.

In the present experiment, the usual thermal reinforcement procedure was modified to include a period of stress induction comparable to the period of deprivation imposed before test in the Guttman procedure. The insertion of the response lever followed the onset of the drive temperature by a 15-sec delay. It was expected that the residual satiating effects of the previous reinforcer would dissipate during the delay. Although the stress level accompanying the opportunity to respond was quite high, it was relatively influenced by the previous reinforcer. It is not possible to specify that the stress was constant on each trial, but, relative to a no-delay control, the effect of the reinforcer on the stress level was certainly smaller.

The purpose of the present experiment is to determine the effect of thermal reinforcement magnitude on response rate when the satiating effect of the reinforcer is reduced. On the basis of work with food reinforcement, it is expected that reduction of satiation will permit the appearance of an incentive effect.

METHOD

Subjects

Three adult male albino rats were used in the experiment (R1, R2, and C1). All had previous experience with thermal reinforcement contingencies. The Ss were individually housed in a temperature controlled room and were maintained at ad lib weight throughout the experiment. All body hair except in the area of the head was removed weekly.

Apparatus

All training and testing was conducted in the convective thermal controller (CTC), which is described in detail elsewhere (Matthews, 1968). The CTC utilized the principle of forced convection to present thermal stimuli in the form of varying air

temperature. Air circulates at a constant speed (15 mph) in three independent systems. The temperature of each system can be precisely controlled at any value from -15°C to $60^{\circ}\text{C} \pm .5^{\circ}\text{C}$, with 32°C equal to behavioral neutrality. A system of valves selects which of the three systems flows through the test chamber and which flows through shunts. When the valves are actuated, 80% of the temperature change in the chamber is accomplished within 1 sec, regardless of the size of the change. Thus, an S could be exposed to any one of three preset temperatures in any sequence dependent upon the programming of the valves.

The test chamber is a transparent acrylic cylinder fitted with a retractable rodent lever (Lehigh Valley Electronics) and jeweled lights. Air passed from the top of the chamber to the bottom in a homogeneous flow.

Solid state switching circuitry, digital counters, and a cumulative recorder were used to program and record events.

Procedure

All Ss were shaped to press the bar with thermal reinforcement. Each had extended experience with thermal reinforcement contingencies prior to the experiment.

In each test session, either a control procedure or the experimental procedure was imposed. The control procedure was similar to the usual thermal reinforcement procedure. Ss responded in the presence of the 50°C drive temperature to produce a thermal reinforcer on a variable interval 5-sec (VI 5-sec) schedule. The reinforcer duration was 10 sec and the reinforcer temperature was either 32°C (small) or 14°C (large). The lever was withdrawn during the reinforcer and reinserted at the onset of the drive condition.

In the experimental treatment, a delay of 15 sec was imposed between the onset of the drive temperature and the insertion of the lever. The VI programmer resumed timing at the insertion of the lever. In all other respects, the experimental treatment was identical to the control treatment.

Ss were tested in daily 100-min sessions, during which the reinforcement magnitude was alternated between small and large every 20 min. The first 20-min block served as a warm-up period and is not included in the data. The reinforcer presented first varied from day to day, and the experimental and control test sessions were presented according to a different random sequence for each S.

RESULTS AND DISCUSSION

The results for Ss R1, R2, and C1 are shown in Fig. 1. The ordinate for each panel is response rate during the drive condition, and the two reinforcement temperatures are shown on the abscissa. The delay and control no-delay conditions are shown as separate functions for each S.

For two of the three Ss, the overall response rate in the delay sessions was faster than in the no-delay sessions. Because the delay condition imposes an additional 15-sec exposure to the drive temperature, it is not surprising that Ss respond somewhat faster. There was, however, a considerable day to day variation in overall response rates for all Ss. S C1 died after only two no-delay sessions, which was not sufficient testing to eliminate the effects of day to day variation.

In the no-delay condition, the usual result occurred for each S; responding was faster with the small reinforcer. Presumably, the large reinforcer has a larger satiating effect on the drive condition which slows responding. This satiation effect was not so clear for R2,

but this was probably due to the short (10-sec) duration of the reinforcer. Matthews (1971) has shown that the satiation effect is usually not large for this reinforcer duration.

The effect of reinforcer intensity in the delay condition was opposite to the no-delay result: Ss responded faster for the large reinforcer. This incentive effect was reliable in all Ss. Figure 2 shows the detailed results for R1. Response rate for small and large reinforcers are separate functions and delay and no-delay conditions are shown in separate panels. In the delay condition, the response rate for the large reinforcer was faster than the response rate for the small reinforcer on every test day ($t = 3.8$, $df = 8$, $p < .005$). On only 1 of 5 test days was the responding for the large reinforcer faster in the no-delay condition ($t = 12.9$, $df = 4$, $p < .005$). Despite large baseline variations, incentive and satiation effects are clearly maintained.

Total reinforcements varied in the same way as response rate. Ss produced the large reinforcer more frequently in the delay condition and less frequently in the no-delay condition. R1, for instance, produced a mean of 39.7 small reinforcers and 42.9 large reinforcers in the delay condition ($t = 9.5$, $df = 8$, $p < .005$) and a mean of 53.7 small reinforcers and 48.2 large reinforcers in the no-delay condition ($t = 12.9$, $df = 4$, $p < .005$).

The results are consistent with an incentive and satiation interpretation. The effect of the 15-sec delay was to restrict the determination of response rate to a period during which the stress level was relatively unaffected by conditions preceding the onset of drive condition. During the delay, stress approaches an asymptotic level that is relatively independent of the stress level at the onset of the drive temperature. Thus, the delay precludes the greater satiating effect of a large reinforcer from affecting response rate by establishing a near constant stress level during responding.

If satiation was the only influence of the reinforcer on response strength, the effect of the delay treatment should have been either a reduction or an elimination of the differential effect of reinforcement magnitude. Instead, the reinforcement magnitude effect inverted, indicating an incentive property of the reinforcer. Although this is a familiar observation when an appetitive reinforcer is used, most studies of thermally motivated behavior have not reflected this property of thermal reinforcers. Woods and his colleagues (Woods, Davidson, & Pebus, 1964; Woods & Feldman, 1966; Woods & Holland, 1966; Woods, 1967) have shown that rats will swim faster for a larger reduction in water temperature but were unable to establish the continuum between satiety and incentive.

The present results indicate that an increase in reinforcer magnitude both increases (incentive) and decreases (satiation) response strength. Because the two effects are opposed, the result of manipulation will always be an average of the two. Thus, the magnitude of the incentive effect demonstrated here is directly

Fig. 2. Day to day average response rate for R1. Dark circles indicate response rate for large reinforcement and open circles represent the same reinforcement condition. Delay and no-delay conditions are shown in separate panels.

reduced by the amount of satiation not excluded by the delay procedure. Because stress constancy cannot be guaranteed by this procedure, the present experiment stands as a demonstration of the incentive property of thermal reinforcers and not as a measure of the true magnitude of the thermal incentive effect.

From the view of thermal motivation as a regulatory process, the incentive effect is not to be expected. Ss should adjust the rate at which they work for reinforcement according to the regulatory effect of the reinforcer. Because a small reinforcer is needed more often to produce regulation, Ss should work harder for it. This is directly opposed to the delay treatment result. It might be argued that the high stress level in the delay treatment prevents regulation and therefore eliminates differential regulatory effects of the two reinforcers. But this would lead to the prediction that Ss would respond equally for the two reinforcers. In fact, they responded faster for the larger reinforcer and produced it more often.

The incentive effect does not contradict the principles of regulatory theory; rather, it lies outside the domain of the theory. Thus, thermally motivated behavior cannot be comprehensively accounted for by a regulatory model.

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