The effect of temperature upon shock-elicited aggression in rats

ROBERT M. BERRY* and CHARLES E. JACK†
Valparaiso University, Valparaiso, Ind. 46383

Sixteen pairs of male Wistar rats received 2.5-mA electric shocks at different rates (12/min or 20/min) under temperature conditions of 40°, 70°, and 100° F. Shock-elicited aggression was a direct function of temperature and was unrelated to shock frequency. There was a slight but nonsignificant ($.05 < p < .10$) tendency for aggressive responses to increase over trials. In Experiment 2, jiggle platform activity was measured in rats at the same experimental temperatures used in Experiment 1. Rats' activity was inversely related to temperature.

The influence of temperature upon aggression has been the subject of considerable lay speculation, with extreme heat presumably increasing aggression. Empirical studies seem not to support lay experience; Scott & Frederickson (1951) trained mice to fight and found that exposures to cold temperatures produced little effect on fighting, while temperatures above 80° F significantly reduced the amount of fighting. Ginsberg & Allee (1942) also report that mice fight less vigorously at higher temperatures. The only report of increased aggression associated with a temperature increase was Wallis's (1962) observation that ants are more aggressive and the aggressive response pattern different at 68°-71.6° F than at 62.6°-66.2° F. The temperature-aggression relation has not been studied in other species partly because of the difficulty in inducing and measuring aggression. The standardization problem recently has been reduced as numerous studies (e.g., Ulrich & Azrin, 1962) have demonstrated that electric shock delivered to the feet is a reliable method of eliciting aggression in a variety of species. When rats are shocked, for example, they adopt a stereotyped "fighting" posture and immediately begin attacking one another.

By measuring shock-elicited aggression under various temperature conditions, it should be possible to obtain a phylogenetic profile of temperature-aggression relations. The purpose of the present experiment is to determine the relationship between temperature and shock-elicited aggression in rats.

EXPERIMENT 1

Subjects

Thirty-two male Wistar rats, approximately 150-165 days of age, obtained from Abrams' Small Animal

Farms, Chicago, Illinois, were used as Ss. The Ss were housed individually in galvanized steel cages, where food and water were available ad lib.

Apparatus

The apparatus included a temperature chamber consisting of an insulated wooden box with inner dimensions of 36 x 36 x 24 in. The inner floor and sides were constructed of ¼-in. wire mesh. An inside light (75 W) was controlled from the outside. A constant supply of fresh air was made available by a vented back wall. Possible temperature settings ranged from 40° to 110° F, with less than 2° variance from the desired setting. The temperatures used in the experiment were 40°, 70°, and 100° F. The front of the box consisted of two doors, each with a 3 x 6 in. window to permit observation of S. Inside the temperature-control chamber was a shock box. The shock box consisted of a standard operant conditioning unit with the lever removed. The grid floor of the shock box was connected to a Lehigh Valley constant-current generator (Model 1531) set to deliver a scrambled shock of 2.5 mA in 0.5-sec pulses. One group of rats received shock every 5 sec, and another group received shock every 3 sec. A Lehigh Valley electronic interval timer controlled the duration and frequency of shock delivery.

Procedure

The 32 rats were paired randomly into 16 pairs of Ss. Eight pairs were assigned to Group 1 and received shock presentations every 5 sec. The other eight pairs were assigned to Group 2 and received shock presentations every 3 sec. Each pair was tested under each of the three temperature settings for a 10-min session with shock present. Each pair was also tested for a 10-min session at each temperature setting with no shock present. No pair was tested twice on the same day. With the exception of this limitation, the order of testing any pair at any temperature was determined randomly. The temperature of the room housing the rats varied around an average of 70° F.

Prior to a testing session, the temperature was allowed to stabilize at the appropriate setting. The shock box was then placed in the chamber, after which a pair of rats was introduced into the shock box. One minute later, shock was delivered to the grid floor of the shock box and continued to appear at the programmed frequency for 10 min. The number of aggressive responses was recorded for each minute of the 10-min interval by two Es observing through the observation windows. At the conclusion of the 10-min session, the rats were removed from the experimental chamber and returned to their home cages. The shock box was also removed to prevent heating of the grid floor.

An aggressive response is defined as an act of biting, scratching, or "punching" by either or both rats while standing in the stereotyped fighting posture. The stereotyped fighting posture is defined as the upright position of the rats while facing each other with head thrust forward and the mouth open. Disagreements in observation were minimal, as the two Es reported better than 95% agreement on what constituted an aggressive response.

Results

No responses were made at any temperature setting the absence of shock. Results of these nonshock trials are not included in the statistical analysis.

The effects of temperature, shock frequency, and trials were analyzed by means of a three-way mixed factorial analysis of variance design, with repeated measures on the temperature and trials factors. The trials factor was arbitrarily defined by dividing the 10-min test session into two successive 5-min sessions. The first 5 min of a test session defined "early" trials, and the second 5 min of a session defined "late" trials.

The mean and SD of aggressive responses for early and late trials are reported in Table 1. Shock rate has been collapsed in Table 1, since neither the effects due to shock frequency nor any of the interactions were significant. The effects of temperature were highly significant ($F = 15.00$, $df = 2/28$, $p < .001$). Since 70° F falls close to the temperature that elicits minimal thermoregulatory

Table 1
Effect of Temperature on Fighting Probability (Aggressive Responses/Number of Shocks) in 16 Pairs of Rats for Early and Late Trials

Temperature	Early Trials		Late Trials	
	M	S	M	S
40° F	.040	.027	.058	.022
70° F	.064	.031	.114	.044
100° F	.128	.061	.134	.040

*Requests for reprints should be sent to Robert M. Berry, Department of Psychology, Valparaiso University, Valparaiso, Ind. 46383.

†Now at the University of Wisconsin, Madison, Wisconsin.

responses and is preferred by rats, additional comparisons were made using the Newman-Keuls procedure to test the significance of cold (40° F) and hot (100° F) departures from this neutral baseline. Relative to the neutral condition, aggressive responses were significantly reduced in the 40° F condition ($p < .05$) and significantly increased in the 100° F condition ($p < .05$). There was also a trend for more aggressive responses to occur during late trials than during early trials, but this difference was not significant ($F = 3.25$, $df = 1/14$, $.05 < p < .10$). Humidity was measured but not experimentally controlled since the temperature chamber was not equipped with humidity controls. The mean humidity measures for the 40°, 70°, and 100° F conditions, respectively, were 48%, 34%, and 21.5%. Since temperature and humidity covaried, an analysis of covariance was performed to remove the bias due to humidity. The result of the covariance analysis was that the between-class correlation was negative ($-.25$) and the within-class correlation was positive (.12, .19, and .25 for 40°, 70° and 100° F, respectively), indicating that the F ratio in the original analysis of variance was actually deflated due to the humidity bias (Winer, 1962).

Discussion

The results indicate that increasing temperature within the limits provided by the present experiment increases the probability of shock-elicited aggression in rats. Temperature was not a specific stimulus eliciting aggression, since no aggression occurred in the absence of shock. The results also suggest that shock-elicited aggression is not a response readily subject to fatigue or adaptation, since there was a slight tendency for aggression to increase within a series of successive shocks.

EXPERIMENT 2

It is possible that the increased aggression observed in Experiment 1 was only an artifact of a general increase in activity level. Increases in activity level seem unlikely, however, since both rats and mice presumably depend on behavioral adaptation and metabolic rate for temperature control. To the extent that temperature effects on aggression are mediated by physiological methods of temperature control, the results of Experiment 1 are especially surprising, since increasing aggression with increasing temperature is maladaptive in the sense of internal temperature regulation. A second experiment was therefore conducted to determine the relationship between temperature and activity level in rats.

Subjects

Eight pairs of male Wistar rats, approximately 130 days of age, were used as Ss. The rats were housed individually in galvanized steel cages where food and water were available ad lib.

Apparatus

The apparatus included the same temperature chamber used in Experiment 1. The shock box was removed and replaced by a Lehigh Valley Electronics jiggle platform (Model 1547), which provided a gross measure of the rats' motor activities.

Procedure

Each pair of rats was transferred to a carrying cage with the same dimensions as the home cage. The carrying cage was then placed in a predetermined location on the jiggle platform. Each pair was tested under each of the same three temperature settings as were used in Experiment 1. Each testing session lasted for 10 min. No pair was tested twice on the same day. Otherwise, the order of testing any pair at any temperature was determined randomly.

Table 2
Effect of Temperature on Jiggle-Platform Activity in Eight Pairs of Rats

Temperature	Number of Pendulum Contacts	
	M	S
40° F	569.38	299.72
70° F	284.38	212.80
100° F	93.50	75.40

Results

The mean and SD of the activity scores for each group are reported in Table 2. An analysis of variance of these data indicated that temperature conditions significantly affected activity ($F = 14.32$, $df = 2/14$, $p < .001$). Additional comparisons were made, using the Newman-Keuls procedure. Activity was inversely related to temperature, with rats significantly more active at 40° F than at 70° F ($p < .05$) and significantly more active at 70° F than at 100° F ($p < .01$).

DISCUSSION

The results indicate that increases in activity, as measured by the jiggle platform, are an inverse function of environmental temperatures between 40° and 100° F. This result is consistent with Scott & Frederickson's (1951) suggestion that rats depend on behavioral adaptation for temperature control. Stevenson & Rixon (1957) have obtained similar results using an activity wheel, and they also point out that activity is one means of increasing body temperature.

The results of Experiment 1, that increased shock-elicited aggression occurs with higher environmental temperatures, cannot be interpreted in terms of increased activity. Instead, the increase in shock-elicited aggression occurs in spite of an opposing tendency to reduce activity with increases in temperature. While the precise mechanisms responsible for the temperature differences in shock-elicited aggression are presently unknown, one possibility is the frustration-aggression hypothesis (Dollard, Doob, Miller, Mowrer, & Sears, 1939; Berkowitz, 1962), provided the definition of frustration is sufficiently flexible to include shock as a frustrating condition. In such a case, temperature can be regarded as increasing the probability of aggression in rats, given the necessary preconditions, i.e., frustration. The hypothesis becomes inadequate if deviations from an optimal temperature are considered an additional source of frustration. Frustration will then be greater at both 40° F and 100° F, suggesting a curvilinear function relating temperature and aggression instead of the direct function obtained.

Another possibility is that one or a variety of neurohumors may be involved as a component of shock-elicited aggression. Temperatures above and below optimal conditions would, respectively, decrease and increase the rats' metabolisms and, hence, the rate at which certain hormones, e.g., norepinephrine and serotonin, are metabolized. Welch (1968) has shown differential aggression to be associated with differential metabolism of such hormones in mice. The formulation based upon the differential metabolism of hormones is consistent with the direct function obtained.

The metabolic hypothesis might also account for the discrepancy in the temperature-aggression relation observed between the present study and those of Scott & Frederickson (1951) and Ginsberg & Allee (1942). The species difference in temperature aggression may represent a species difference in component hormones or in the metabolism of these hormones. Still another possibility is that the difference in temperature-aggression relations represent, not a species difference, but operational differences between the two studies. Further studies are needed to investigate the temperature-aggression relation in a variety of species under comparable conditions.

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85 dB inside the chamber. The CS was a high-frequency (approximately 80 Hz) train of clicks, which raised the noise level to about 93 dB. Food reinforcers consisted of 3 sec of access to mixed grain. Automatic programming and recording equipment were in an adjacent room.

PROCEDURE

In Phase 1, all Ss were given six sessions in which a 10-sec CS and a food reinforcer were present 60 times each, independently of the birds' behavior. In the paired group ($N = 8$), food was always delivered immediately following the CS, with the CS occurring on a variable-interval (VI) schedule with a mean of 60 sec (range: 30-90 sec). In the random group ($N = 6$), the CS and food were presented on independent VI 60-sec schedules. In Phase 2, the birds were trained to peck a red response key by the method of successive approximations and were then given six 60-reinforcement sessions, with pecks reinforced on a VI 30-sec schedule during the first session and on a VI 60-sec schedule during the last five sessions. No CSs were presented during Phase 2. In Phase 3, all birds were given two more sessions identical to Phase 1. Throughout Phases 1 and 3, photocell responses were recorded every time the photocell beam was broken during the 10-sec CS intervals and also during 10-sec intervals immediately preceding each CS presentation. The response key was covered by a cardboard patch during Phases 1 and 3.

On the day after the last Phase 3 session, each bird was given a 10-reinforcement warm-up of Phase 2 training, followed by a 2-h test session during which no reinforcers were delivered (extinction). In the test session, CS was presented for 60 30-sec trials, with from 60 to 120 sec between trials. The first test trial occurred after 60 to 120 sec of extinction. Photocell and keypeck responses were recorded during CS intervals and also during 30-sec intervals immediately preceding each CS presentation.

RESULTS

Peck- and photocell-response data were transformed into two different ratios which express the relative difference in response totals during pre-CS intervals (A) vs CS intervals (B). The directional difference ratio equals B divided by $A + B$; this ratio can range from 0 to 1.0, with values greater than 0.5 indicating more responding in CS and values below 0.5 indicating less responding in CS, as compared to the pre-CS interval. The nondirectional difference ratio equals A or B , whichever is smaller, divided by $A + B$; this ratio can range from 0

Effect of a signal previously paired with free food on operant response rate in pigeons*

G. WILLIAM FARTHING

University of Maine, Orono, Maine 04473

In Phase 1, food was presented independently of the birds' behavior. In one group, the food was paired with an auditory CS; in the other group, CS and food occurred randomly. In Phase 2, the birds were trained to peck a key for variable-interval food reinforcement, with CS off. Then, following additional Phase 1 training, they were tested with CSs presented during operant extinction. For both keypecking and a photocell measure of activity near the speaker, the CS produced changes in behavior which, when measured independently of the direction of change, were significantly greater in the paired group than in the random group.

Rescorla & Solomon (1967) have discussed the importance of studying interactions between classical and operant conditioning by superimposing classical CSs on operant response baselines. In an experiment which involved positive reinforcement during both the classical and operant conditioning phases, Estes (1948) gave rats several tone-food pairings, then trained them to press a lever for food reinforcement, and finally presented the tone occasionally during operant extinction; operant response rates increased during tone presentations. The present study was an attempt to

replicate Estes' (1948) experiment, using pigeons as Ss.

SUBJECTS AND APPARATUS

Fourteen experimentally naive Silver King pigeons (5-8 years old) were maintained at 75% of their free-feeding body weights. An operant conditioning test chamber was equipped with a response key, houselight, and feeder. A 6-cm-diam speaker was mounted behind perforations in the upper left corner of the intelligence panel, about 14 cm from the response key. A photocell was mounted about 3 cm from the lower left edge of the speaker, and light was projected on the photocell through an opening in an aluminum box that was suspended 15 cm in front of the speaker. External sounds were masked by a white noise in the room, which produced a noise level of about

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