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Effects of Coping Response on Stress in a Discrete-Trial Lever-Press Escape Situation in Rats

(coping response/relevant feedback/basal emotional level)

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Effects of coping response with electric shocks upon stress under the conditions in which the amount of relevant feedback was minimized were examined under both signaled and unsignaled shock conditions in a discrete-trial lever-press escape situation using 28 rats. One group of rats could escape shock by pressing the lever, the other was yoked with the above group with respect to shock experience. For half of the rats in each group shock was signaled, but for the other half it was unsignaled. The above shock treatments were superimposed upon drinking behavior. There was significantly less suppression of overall drinking in both Escapable groups than in the Yoked control groups, indicating the stress-reducing effects of coping response with respect to the basal emotional level (BEL), but no difference was found in the conditioned emotional response (CER), in both signaled and unsignaled shock conditions.

A considerable number of experimental studies have shown that rats which had control over electric shocks lost less body weight (1), developed fewer gastric ulcers (1—4), and showed less fear as measured by suppression of eating (5), drinking (6, 7), and operant responses (8) as compared with the yoked rats which received exactly the same electric shocks but did not have control over them. A general conclusion drawn from these facts is that the psychological effects of coping with shocks should reduce stress (or fear).

How, then, should the above facts be explained? One of the factors which Weiss (2) has emphasized in his theory was "the amount of relevant feedback" which coping responses produced. Weiss regarded it as the extent to which a response produced the stimuli not associated with stressors. He stated that the excellent feedback might come from escape response because of its very large change in the external stimulus situation involving shock termination (2). Besides, in his free-operant situation, rat that could cope with the electric shocks could delay the next shock by turning a wheel at any time during the session, thus always could generate a shock-free (safety) period by themselves. Thus proprioceptive feedback from the response could become associated with safety. This, however, was not the case in the yoked group in which there was no contingency between rats' responses and safety.

In line with Weiss' theory it would appear that the greater the amount of relevant feedback, both extrinsic and intrinsic, the greater the advantage the experimental rats would have over the yoked rats. There are several ways to manipulate the amount of relevant feedback and the following are the conditions to reduce this amount : 1) To use the experimental situation in which the coping is not a locomotion from a danger segment of the apparatus to the safe one. This suggests the use of a manipulandum such as a lever or a wheel, responses on which take subjects no where. 2) Not to use a manipulandum which requires much effort to manipulate or which produces much proprioceptive feedback from responses. 3) Not to allow subjects to generate safety periods at any time during the experiment. This suggests the use of a discrete-trial situation rather than a free-responding situation. 4) Not to use a signal, the termination of which by a coping response may function as a good extrinsic feedback.

The purpose of the present experiment was to investigate the effects of availability of the coping response with electric shocks upon stress under the conditions in which the amount of relevant feedback was minimized under both signaled and unsignaled shock conditions. In both conditions, the fixed-electrode method was used to assure the physical equality of the shocks in both shock-escapable and shock-inescapable yoked groups.

MATERIALS AND METHODS

Subjects

Forty experimentally naive male albino Wistar rats were used as subjects, but 4 of them were discarded at the time of grouping because of extreme body weight or unstable criterion responses of licking. The mean body weight of the remaining 36 rats was 324.0 g when the escape conditioning began.

Apparatus

Two identical lever-boxes were used during the main part of the experiment. Each box, having a grid floor and made mostly of unpainted brown bakelite plates, was 175 mm long, 100 mm wide and 150 mm high (inside dimensions). The front panel had a tube for drinking as well as a lever for terminating the shocks and the rear panel had a hole through which rat's tail was led out of the box and attached to the shock electrode. The left half of the front panel, made of clear plexiglas, had a hole (12 mm in diameter and 40 mm above the grid floor) through which the rat could gain access to the drinking tube. Protruding by 10 mm from the right half of the front panel was a lever (45 mm wide and 5 mm thick), the depression of which was made possible only by having the wall withdrawn by 25 mm by means of a solenoid. Thus the size of the lever, when protruding from the front panel, was 45 × 35 (mm). The surface of the lever was 45 mm above the grid floor. The hole of the rear panel was 12 mm in diameter and located at 26 mm above the grid floor. The tail of the rat was slid into this hole and taped to the electrodes outside the rear panel of the box. The ceiling, made of a clear plexiglas plate, tilted toward the rear panel, so that the height of the ceiling was 150 mm at the front and 100 mm at the rear panel.

A 5 W lamp suspended approximately 300 mm above the grid floor of the apparatus, over the tube and lever area, was a source of illumination inside the box. The boxes were placed on a table in parallel approximately 300 mm apart.

The CS was a tone, 85 dB (c), 1000 Hz, generated by an oscillator and presented through a speaker which was located 1500 mm directly above the floor of the apparatus. The US was an electric shock delivered from the AC-shock source to the tail-electrode through a 250 Kohm current limiting resistor put in series with the rat. The shock was delivered in brief pulses (.2 sec duration) which occurred at the rate of 3 per sec. The duration of the CS and US and their temporal relations were all controlled by timers. The experimenter presented the CS and US, and recorded the number of rat's licks at the tube by a print-out counter in 5 sec intervals in the room next to the experimental room. A fan placed in the experimental room provided the background masking noise of approximately 65 dB (c), measured inside the boxes.

During the preliminary training of drinking, 4 identical drinking boxes (200 × 100 × 150 mm, inside dimensions) described in detail by Yoshida *et al.*(9) were also used.

Procedure

1) Handling and Habituation to the Watering Schedule

For 5 days immediately preceding the training of drinking, all rats were tamed by handling for 5 min per day. After handling, rats were put on an 1 hr/day watering schedule which was maintained throughout the experiment.

2) Preliminary Training of Drinking

For the first 24 days the rats were trained to drink water from the tube individually for 5 min per day in the drinking boxes. They were run four at a time in the manner described in detail by Yoshida *et al.*(9). For the following 18 days, the training of drinking took place in the two lever-boxes with the rat's tail taped to the electrodes except for the first five days. The training of drinking both in the drinking box and the lever-box took place every day always after approximately 22.5 hrs of water deprivation.

By the end of 42 days of the above preliminary training of drinking, the number of licks in the daily 5 min session stabilized. All rats were then paired and the two animals of each pair were matched in the number of licks and body weight. Four rats were discarded at this stage because of unstable licking or extreme body weight. The mean number of licks per session of the remaining 36 rats was approximately 1480.

3) Escape Conditioning

Shock treatment was carried out for the following 30 days and was superimposed upon the drinking behavior. All matched pairs of rats were assigned randomly to one of the two different conditions, one being designated as the signaled condition, in which the electric shock was preceded by 10 sec CS, and the other as the unsignaled condition, in which no CS was presented. Then each within the matched mair in each condition was assigned randomly to one of the two different groups, one being designated as the Escapable subject, which had control over the duration of shock by its response, and the other as the Yoked subject, which received exactly the same shocks as the Escapable subject but had no control over shocks. All experimental treatments were carried out simultaneously on pairs of two rats.

Before the daily treatment, the electrodes were attached to the tail of both Escapable and Yoked rats by using electrode paste. In order to assure firm contact of the electrodes with the tail, hair remover was also occasionally rubbed on the shocked site of the tail.

The electric shocks were presented two, three or four times per session, with the mean of three, immediately preceded by 10 sec CS in signaled condition but by no CS in unsignaled condition. The lever was made available to the rats to press simultaneously with the shock-onset and hence the shock-avoidance was not possible. Responses to the lever by the Yoked rats were not functional. Both the CS and/or the shock continued until the Escapable rat pressed the lever or to the maximum of 9.9 sec when no response occurred. The interval between the US-offset and US-onset was varied within the range of 20—140 sec, with the mean of 76 sec. The shock intensity was 60 Vac to start with but was gradually increased to the maximum of 150 Vac.

RESULTS

Due to an equipment malfunction or extremely poor escape response rate, data for 8 rats of four pairs (four rats in each condition) were lost.

Fig. 1 shows the mean median latency of Re for signaled and unsignaled escapable subjects, in blocks of 18 trials. A 2 (Conditions) by 5 (Blocks) Lindquist's Type I ANOVA (10) conducted on the data showed the main effect of Blocks was significant ($F = 16.18$, $df = 4/48$, $p < .01$), though the main effect of Conditions and Conditions by Blocks interaction were not. The results thus showed clear evidence of learning of escape response to shock in both conditions.

Fig. 2 shows the mean number of total licks of four groups in blocks of 6 days. A 2 (Group) by 5 (Blocks) Lindquist's Type I ANOVAs (10) were conducted on that data for the signaled and unsignaled conditions separately. In both conditions the main effect of Blocks ($F = 19.12$, $df = 4/48$, $p < .01$; $F = 29.83$, $df = 4/48$, $p < .01$; for signaled and unsignaled conditions, respectively) and Groups by Blocks interaction ($F = 2.59$, $df = 4/48$, $p < .05$; $F = 2.56$, $df = 4/48$, $p < .05$; for signaled and unsignaled conditions, respectively) were significant. It is clear from Fig. 2 that in both signaled and

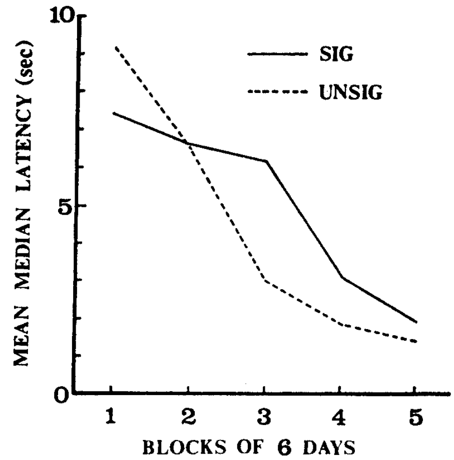

Fig. 1. Mean median latency in signaled escapable group (n = 7) and unsignaled escapable group (n = 7).

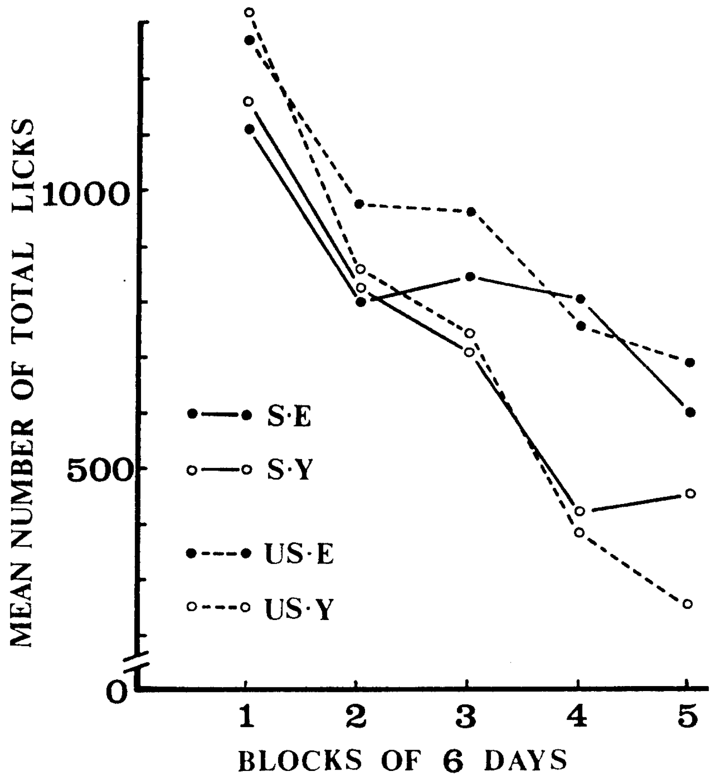

Fig. 2. Mean number of total licks in 5 min as a function of experimental conditions and training (S : signaled, US : unsignaled, E : escapable, Y : yoked).

unsignaled conditions, the availability of escape response to electric shock had stress-reducing effects which are reflected by the significantly less suppression of licking in the Escapable groups. It is also clear, by comparing Figs. 1 and 2 that this stress-reducing effect found in the Escapable rats became more

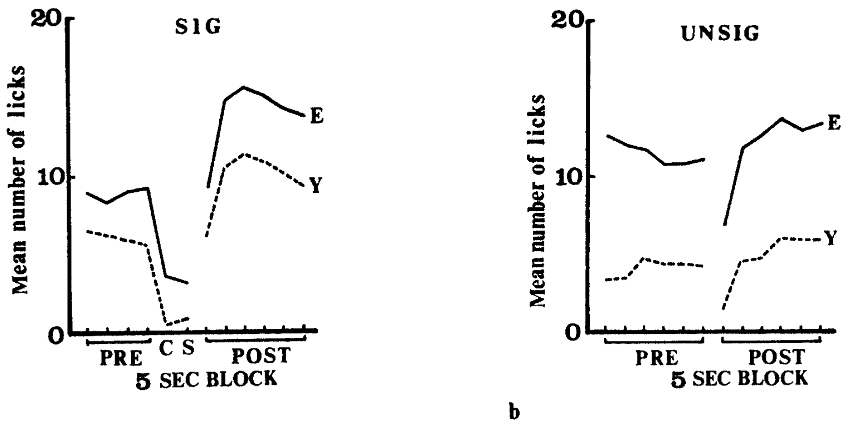

Fig. 3. Mean number of licks in 5 sec blocks during pre- and post-shock 30 sec. At top (a) the results for the signaled shock condition are shown and at bottom (b) those for the unsignaled shock condition are presented.

apparent as a function of acquisition of escape response.

Fig. 3 shows the mean number of licks in blocks of 5 sec periods during pre- and post-shock 30 sec on the final block of training in signaled and unsignaled conditions. As shown by the curves, the mean number of licks in Escapable groups in both conditions outnumbered that in Yoked groups in all intervals. A marked suppression of licking by the CS presentation was found in both groups in the signaled condition, but no significant difference was found on the suppression ratio (SR) which was obtained by the formula of Annau and Kamin (11).

Behavioral difference of two escapable groups seems apparent in the first post-shock 5 sec-interval. In contrast to prompt recovery in licking after the shock in signaled escapable rats, unsignaled escapable rat's licking recovered gradually. Possibly this prompt recovery phenomenon in the signaled group would have been due to the presence of the termination of signal (tone), a "good" external feedback stimulus.

These results indicate that the availability of coping response is effective in reducing stress induced by the total experimental situation or in reducing basal emotional level (BEL) (12) which provided the basis for the CER.

DISCUSSION

In this study the effects of coping response with shock on stress were examined in a discrete-trial lever-press escape situation in two different signal conditions. In both conditions rats which had control over shocks by their response showed less fear compared with the yoked rats which received exactly the same shock but had no control over them.

In order that the difference in stress in groups differing in the controllability of the shocks can be explained by psychological effects of coping, physical equality of shocks in both groups has to be well guaranteed. In a conventional grid-floor situation, it is not at all inconceivable that various postures or patterns of activity might reduce shock intensity physically (13). This possibility may function as a critical source of difference in stress of both groups especially in the situation where a locomotive coping response is involved (6). It is for this reason that a fixed-electrode method was adopted in this study. The results obtained provided further support to psychological stress-reducing effects of coping response.

Weiss (2) hypothesized that the degree of stress ulceration can be determined by the amount of appropriate (relevant) feedback which coping attempts produce and the ulceration tends to decrease monotonically as the relevant feedback increases. He acquired evidence supporting his hypothesis by showing that giving the avoidance-escape rats a tone as an additional cue whenever they rotate the wheel far enough to perform the correct response causes them to develop even less stomach lesions than rats which did not receive this cue (4).

Similar results were obtained in this study in which the amount of relevant feedback was minimized —— by not requiring locomotive and effortful coping response, by not allowing subjects to generate safety period at any time and by not using a signal (Unsignaled condition).

In an avoidance conditioning situation, since the cues produced by performing the successful avoidance responses are never immediately followed by shock, they become the negative cues of a discrimination and hence come to have a conditioned inhibitory effect on fear. Such a mechanism, as Moscovitch and LoLordo (14) reported on the conditioned inhibition in a backward conditioning paradigm using shocks as US, might be working in the present escape situation in which shocks were invariably delivered, but making the required escape guaranteed a shock free interval. This conditioned inhibitory effect on fear produced by Escapable rat's coping response should reduce the basal emotional level which is measured by the number of licking responses.

On the other hand, it has been shown that inescapable, helpless yoked rats showed a variety of maladative behavior (15, 16, 17). Seligman and Maier (18) reported the striking interference with performance when inescapable rats were later tested for escape-avoidance situation. Recently Miller (19) reported evidence that the depressed level of the neurotransmitter norepinephrine in the brain by the presentation of inescapable electric shocks interfered with the performance. Thus, by deliveries of uncontrollable electric shocks various changes should occur physiologically and/or behaviorally.

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