EFFECTS OF COPING BEHAVIOR IN DIFFERENT WARNING SIGNAL CONDITIONS ON STRESS PATHOLOGY IN RATS

JAY M. WEISS
Rockefeller University

Rats received electric shock that was preceded by either a warning signal, a series of signals forming an "external clock," or no signal at all. In all conditions, subjects which could avoid and/or escape shock developed less ulceration than did yoked "helpless" animals which received exactly the same shock (through fixed electrodes wired in series) but had no control over shock. Presence or absence of a warning signal did, however, have an effect: A discrete warning signal reduced the ulceration both of subjects having control over shock and of yoked helpless subjects. A theory is proposed to explain how psychological factors determine the development of gastric ulceration in stress situations, and the present results are examined in relation to it.

In 1968 I reported that rats which could avoid or escape electric shocks lost less body weight, developed fewer stomach ulcers, and showed less fear in a stressful situation (as measured by a CER test) than did rats which received exactly the same electric shocks but could not avoid or escape them (Weiss, 1968a). A previous study which had also examined the effects of coping behavior on the development of psychosomatic pathology obtained results opposite to these. Brady, Porter, Conrad, and Mason (1958), in a study which became known as the "executive" monkey experiment (Brady, 1958), found that in four pairs of monkeys, animals which could avoid electric shocks eventually developed severe gastrointestinal pathology and died, while animals which received the same electric shocks but could not perform the avoidance response developed no discernible disorders. In the 1968a paper, I discussed the possible reasons why my results were opposite to those of Brady et al. Although the studies in question were carried out on different species, and there was an unfortunate selection factor in the executive monkey experiment (i.e., the avoidance and yoked subjects were not chosen at random but, rather, a 2-4 hr. avoidance pretest was given to each pair and the monkey responding at the higher rate was always made the avoidance animal), nevertheless it was plausible that the opposite results were due largely to different experimental conditions used in the two studies. The present experiment investigated this possibility.

This experiment examined the importance of warning signals in the coping situation. In the original studies I carried out, where the animal able to perform the coping response developed less severe symptomatology than its helpless partner, the shock was always preceded by a tone signal, a standard avoidance procedure. Thus, the tone always predicted the occurrence of shock and could serve as a signal for the animal to respond at the appropriate time. In the executive monkey experiment, on the other hand, shock was not preceded by a signal, for a Sidman avoidance schedule was used. In this avoidance situation, the animal postponed (avoided) shock with each response but it had no external signal to inform it that shock was imminent so it had to make a temporal discrimination in order to predict when shock would occur and respond appropriately. This Sidman avoidance response may be considerably more difficult to maintain than is a signaled avoidance response; therefore, having to maintain a coping response in an unsignaled shock situation might be more stressful than being unable to perform any effective response, whereas the reverse is true when the impending shock is clearly signaled. If

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2 Requests for reprints should be sent to Jay M. Weiss, Rockefeller University, New York, New York 10021.
this were correct, it would afford an explanation for why the effects of coping behavior were opposite in my studies and in the executive monkey experiments.

In the present experiment, the effects of three different warning signal conditions were studied. In each of these conditions, matched triplets of animals underwent experimental treatment simultaneously, each triplet consisting of an animal which could avoid or escape shock, a yoked animal which received exactly the same shocks (and warning signals) as the avoidance-escape subject but which had no control over shock, and a nonshock control animal. In the first warning signal condition, a signal (beeping tone) preceded shock by several seconds, which formed a signaled coping-response situation for those subjects able to avoid and escape shock. In the second condition, no signal preceded shock, which formed an unsignaled, or Sidman-type, coping-response situation for avoidance-escape subjects. In the third condition, called the progressive-signal condition, the beep signal preceded shock as in the first condition but, in this case, a series of tones, each increasing in frequency and amplitude, led up to the beep. Thus, animals in this condition were provided with an "external clock" giving them even more information to predict the occurrence of shock than was present in the signal condition. The effect of these conditions was examined primarily upon the development of gastric ulcers. Steroid concentration in the blood was also measured since steroids may participate in the ulcerogenic processes. The amount of body weight lost during the stress session was observed as well.

**Method**

**Subjects**

The subjects were 180 male albino Sprague-Dawley rats obtained from Hormone Assay Laboratories (Chicago, Illinois). The animals weighed approximately 180–250 gm. at the time of the experiment.

**Apparatus**

The apparatus consisted of individual Plexiglas avoidance-escape chambers housed in soundproof compartments (Industrial Acoustics, Inc., New York; Model AC-1) as shown in Figure 1. The wheel at the front of the avoidance-escape chamber, when rotated by the animal, tripped a switch that could be activated to produce escape from, or avoidance of, electric shock delivered to the tail. The shock source was a high-voltage ac step-up transformer (1,200-v. peak output) with a 300 K external resistance in series with the subjects, and the current was varied by regulating the primary voltage input to the transformer. Auditory signals originated from Ameco Code practice oscillators and were delivered through 4-in. Lafayette 8-ohm speakers (No. 99-0172) with three speakers (one in each of three compartments) wired in parallel.

**Procedure**

All experimental procedures were carried out simultaneously on three animals (a triplet). The three animals of each triplet were matched for body weight (within 15 gm. of one another) when drawn from the colony and were then housed together in one cage where they had access to water but no food. Twenty-four hours later, each animal was weighed and placed into a chamber inside an individual soundproof enclosure (described above). Prior to each subject's being placed into its chamber, a lightweight aluminum disk was slipped onto the animal's tail and a piece of tubing was secured to the tail behind the disk (see Figure 1); this assembly prevented the animal from pulling its tail completely into the chamber while permitting the animal to turn over, move backward, and also move forward up to the point where the tubing came in contact with the disk. Behind the disk and tubing, shock electrodes, consisting of two 2-cm. lengths of 18-gauge stainless-steel tubing, were
placed onto the tail after electrode paste was rubbed lightly onto the site of electrode contact. The three subjects were then randomly assigned to the avoidance-escape subject, the yoked control subject, and the nonshock control subject. The tail electrodes of the avoidance-escape animal and its matched yoked animal were wired in series, so that the shocks received by these two subjects were identical in number, duration, and current intensity throughout the entire experiment. The electrodes of the nonshock subject were bypassed in the circuit so that this subject was never shocked.

**Warning signal conditions.** Each triplet was also assigned randomly to one of the three warning signal conditions (signal, progressive signal, no signal) which are diagrammed in Figure 2a. In the signal condition, a beeping tone preceded shock by 20 sec. The beep was produced by 1-sec. pulses of a 555-cps tone with 3 sec. between pulses. In the progressive-signal condition, shock was also preceded by the beep as in the signal condition. In this case, however, an ascending series of tones occurred in the 180-sec. period prior to the beep. This 180-sec. period was divided into six 30-sec. periods. Following the first 30-sec. period, during which no tone occurred, the tones commenced, each lasting 30 sec. and each increasing in frequency and amplitude with respect to the previous one. The frequencies for the ascending tones in this series were 250, 275, 333, 385, and 555 cps. In the no-signal condition, no signal of any kind preceded shock.

The effect of these different warning signal conditions on the avoidance-escape schedules was as follows: The basic response-shock contingency was the same in all three warning signal conditions. In all conditions, if the avoidance-escape animal turned the wheel at the front of its apparatus, the signal-shock sequence was immediately terminated and begun again; i.e., the signal-shock sequence was reset to the time marked "0" in Figure 2a. Thus, if shock had begun, a response terminated shock immediately and delayed the next shock for 200 sec.; if shock had not yet begun, the response postponed shock for 200 sec. An avoidance-escape response therefore had the same effect on shock frequency regardless of the warning signal condition—the response always delayed the next shock for 200 sec. A response, in resetting the signal-shock sequence, also immediately terminated any warning signal (or CS) that was present, as is standard procedure in signaled avoidance-escape situations. Thus, if an animal in the signal condition responded during the beep prior to shock, the beep immediately terminated, and if an animal in the progressive-signal condition responded during one of the ascending tones or the beep preceding shock, the tone or the beep immediately terminated. Figure 2b shows the effect of the same hypothetical response pattern on stimuli (tones and shocks) in the signal condition (upper section), progressive-signal condition (center), and no-signal condition (lower). A total of 60 triplets (20 in each condition) were used.

**Stress-session procedure.** At the beginning of the session, the avoidance-escape animal received a brief period of training (30 min.) in wheel turning. The shock, which was administered in pulses (pulse duration, 2 sec.; interpulse interval, 0.6 sec.), was kept at a low intensity during this phase (not exceeding 1.0 ma.). On the initial trials, the shock was reduced or terminated whenever the avoidance-escape animal moved toward the wheel and increased slightly when the animal moved away from the wheel. Once the animal had learned to turn the wheel, the shock was set at a low level (.5–6 ma.) for the remainder of the training period. Trials were presented at the rate of 1/min during this training phase. It should be noted that yoked animals, being wired in series with avoidance-escape animals, received all shocks that were received by avoidance-escape animals during all phases of the experiment, including the training period.

At the conclusion of the initial training period, standard conditions (as described in the previous section on warning signal conditions) were initiated. The shock, delivered in pulses as described in the previous paragraph, was initially set at an intensity of 1.6 ma., and every 12 hr. the intensity was increased by .6 ma. The stress session lasted for 48 hr. Water was available ad lib throughout the session, and the amount consumed was recorded.

At the end of the stress session, the animals were quickly removed from the apparatus, weighed, and sacrificed by decapitation. Blood was collected for plasma corticosterone determination. The time required to remove an animal from the apparatus—from the opening of the compartment door to decapitation—did not exceed 1 min., so that steroid levels were not affected by the removal procedures. Stomachs were removed, opened, and mounted for inspection (see Weiss, 1968a, for details of the procedure).

**Measures and Statistics.** Stomach ulceration was the primary stress symptom measured in this experiment. Stomachs were
examined under a dissecting microscope and lesions were counted. The criteria for identification of lesions by gross inspection of tissue can be found in an earlier paper (Weiss, 1968a). Recent experiments (Ganguly, 1969; Sethbhakdi, Pfeiffer, & Roth, 1970) have demonstrated the importance of quantifying the amount of the gastric mucosa which is ulcerated, having shown that measures which do not reflect this are insensitive to differences produced by known ulcerogenic conditions. Therefore, the length of each lesion was measured, a method used previously in this laboratory (Weiss, 1968a, 1970); the total length of lesions found in each subject constituted the principal measure of amount of ulceration. In addition to gastric lesions, body weight change during the session and plasma corticosterone concentration at the time of sacrifice were measured. Plasma corticosterone was

Statistical analysis was carried out using non-parametric tests of significance, since the scores on most measures were not normally distributed. The following statistical tests were used: For comparisons between avoidance-escape, yoked, and non-shock subjects of the same warning signal condition, Wilcoxon signed-ranks tests for matched subjects were used. (Since one subject from each of these groups was included in each triplet, these groups all contained matched subjects.) For comparisons between groups that were not of the same signal condition, Mann-Whitney U tests were used.

RESULTS

Wheel-Turning Behavior (Avoidance-Escape Responding)

Table 1 shows the median number of wheel-turning responses for all groups and the median number of shocks received by animals in each condition. As expected, avoidance-escape animals made significantly (at least \( p < .05 \)) more responses than yoked animals in each signal condition.

Avoidance-escape subjects showed a wide variety of response patterns, particularly in conditions where a signal preceded shock (signal and progressive-signal conditions). The total number of responses made by avoidance-escape subjects in the signal condition ranged from slightly over 1,500 to more than 20,000, and the range was similar for subjects in the progressive-signal condition. Approximately 70% of the avoidance-escape animals in these two signaled-shock conditions did not often respond during the beep signal preceding shock but responded quickly after the shock began, thus terminating it; i.e., they primarily escaped from shock. This accounts for the high number of shocks in these conditions. The remaining 30% of the animals in each of these conditions, on the other hand, consistently responded during the beep prior to the shock, terminating this signal and avoiding the impending shock. In the no-signal condition, avoidance-escape animals also showed considerable variation in responding (range: 3,200–31,000 responses) but the most striking feature of this group was its generally high response rate. These avoidance-escape animals made more responses than avoidance-escape subjects in the signal condition (\( p < .001 \)) and progressive-signal condition (\( p < .005 \)), which accounts for the lower number of shocks received by animals in the no-signal condition. Yoked animals in the no-signal condition also showed more wheel-turning behavior than yoked animals in the signal condition (\( p < .001 \)) but not significantly more than yoked subjects in the progressive-signal condition.

Stomach Ulceration

Gastric lesions, commonly called stress ulcers, were found in the lower, glandular area of the stomach. Figure 3 shows such a lesion as it appeared in the stomach, and also a histological section of this lesion. No lesions were found in the upper, rumenal area of the stomach.

Figure 4 shows the amount of lesioned gastric tissue (length of lesions) found in each group, and the confidence levels for all significant comparisons. Figure 5 shows the same for number of lesions.

Within all three signal conditions, avoidance-escape animals showed less extensive gastric ulceration than did yoked animals. The difference between the avoidance-escape and yoked groups was statistically significant in each condition on at least one of the two measures, with the largest difference between these groups clearly occurring in the progressive-signal condition. Non-shock animals, which developed a small
amount of ulceration as a result of the 48-hr. restraint in the apparatus, showed less ulceration than the animals which received shock (avoidance-escape and yoked groups), as expected.

Examining differences between warning signal conditions showed that avoidance-escape animals developed more ulceration in the no-signal condition than they did in either the signal or progressive-signal condition, in which avoidance-escape animals developed similar amounts of ulceration. Thus, animals able to avoid and escape when shock was not preceded by a signal showed less ulceration. As stated in the previous paragraph, in no case did avoidance-escape animals develop more ulceration than matched yoked subjects. Comparing yoked animals across conditions, ulceration was also more extensive in the no-signal condition than it was in the signal condition. Ulceration of yoked animals in the progressive-signal condition, however, was almost as severe as that which occurred in the no-signal condition.

It should be noted that the ulceration of avoidance-escape animals which consistently terminated the beep signal before shock did not differ markedly from those avoidance-escape animals in the same signal conditions which did not do so. In the signal condition, for example, the median amount of ulceration for the entire group was 1.12 mm.; for subjects with a large number of beep terminations (150 or more; n = 5), it was 1.25 mm.

**Body Weight Loss**

Figure 6 shows body weight loss during the stress procedure for all groups. Yoked animals in the progressive-signal and no-signal conditions lost significantly more weight than did avoidance-escape animals; the weight loss difference between these groups in the signal condition was quite small and did not approach significance. Nonshock animals lost less weight than shocked groups (avoidance-escape and yoked subjects) in all conditions.

![Figure 6](image-url)

**Fig. 4.** The median total length of gastric lesions for the nonshock, avoidance-escape, and yoked groups in the signal, progressive-signal, and no-signal conditions. Also shown are the confidence levels of all comparisons between groups for which the chance probability was .10 or less. Twenty matched triplets were used in each signal condition.
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Signal Progressive No signal

Fig. 5. The median number of gastric lesions for the nonshock, avoidance-escape, and yoked groups in the signal, progressive-signal, and no-signal conditions. Also shown are the confidence levels for all comparisons between groups for which the chance probability was .10 or less. See Figure 4 for key.

Significance of comparisons across conditions are shown, but because of the variation in weight loss observed across conditions (e.g., compare nonshock groups), care should be taken in interpreting differences on this measure which are not based on comparison of groups of the same signal condition which had matched subjects.

It should be noted that prestress weight, which was taken prior to the placement of the animals into the apparatus for the stress procedure, was highly similar for all groups. The average weight across the nine groups of the experiment showed a range of only 3 gm.; the average weight of the lightest group was 212.5 gm. compared with 215.5 gm. for the heaviest group; no difference approached significance.

Plasma Corticosterone

Levels of plasma corticosterone at the termination of the stress session are shown for all groups in Figure 7. Individual variation was considerable, which is not surpris-

* Weight includes the tail-guard assembly, which was in position on the tail when this weight was taken. The entire assembly contributed approximately 210 gm. to this weight. The animal did not, however, support the weight of the assembly in the apparatus, as can be seen in Figure 1.

Plasma steroid level did, however, correlate with amount of ulceration. The average correlation for all groups which received shock (avoidance-escape and yoked subjects in each of the three signal conditions) was \( r = .52 \). This correlation was mainly attributable to subjects with very high steroid levels which invariably showed extensive ulceration—in those subjects where the steroid level exceeded 70 \( \mu g \) per 100-ml plasma, the amount of ulceration averaged 21.2 mm.

Water Intake

In all signal conditions, avoidance-escape and yoked animals drank significantly (at least \( p < .01 \)) more water than nonshock

Fig. 6. The median amount of body weight lost during the stress session by the nonshock, avoidance-escape, and yoked groups in the signal, progressive-signal, and no-signal conditions. Also shown are the confidence levels for all comparisons between groups for which the chance probability was .10 or less. See Figure 4 for key.
FIG. 7. The median concentration of corticosterone in the blood at the conclusion of the stress session for the nonshock, avoidance-escape, and yoked groups in the signal, progressive-signal, and no-signal conditions. Also shown are the confidence levels for all comparisons between groups for which the chance probability was .10 or less. See Figure 4 for key.

animals, which is consistent with findings that water intake (in the absence of food) is increased when animals are exposed to stressful conditions (e.g., Deaux & Kakolewski, 1970). In the progressive-signal condition, yoked animals drank more water (Mdn = 40.0 ml.; p < .02) than did matched avoidance-escape subjects (Mdn = 33.0 ml.); no other significant difference was found between avoidance-escape and yoked groups.

DISCUSSION

The present experiment showed that regardless of whether electric shock was preceded by a warning signal, by a series of warning signals forming, so to speak, an external clock, or by no signal at all, rats that could perform coping responses to postpone, avoid, or escape shock developed less severe gastric ulceration than matched subjects which received the same shocks but could not affect shock by their behavior. Thus, the possibility discussed in the introduction—namely, that the absence of a warning signal before shock might result in more pathology in animals able to avoid or escape shock than in helpless yoked animals—was not borne out. Since the executive monkey phenomenon, i.e., the occurrence of more pathology in avoidance-escape subjects than in yoked animals, was not found in any condition, the present results offer no rationale for reconciling my earlier results with those of the executive monkey experiment. Instead, the present results, in combination with earlier experiments, serve to establish that the beneficial effect of coping behavior in stressful situations is of considerable generality.

The present results point out again the extraordinary significance of psychological factors in the production of stomach ulcers. If, in Figure 4, we compare the gastric ulceration of any nonshock group with that of the avoidance-escape animals in the signal and progressive-signal conditions, we can see that simply receiving shock was not necessarily very harmful in and of itself. These avoidance-escape animals clearly ulcerated more than did nonshock controls; however, the amount of ulceration in these avoidance-escape animals was not very large. Now let us compare either of these avoidance-escape groups with the yoked animals in the no-signal condition. The difference here was produced by psychological variables, by differences in warning signals and the ability to control shock, and not by the presence or absence of the shock stressor, since all subjects in this comparison received shock (in fact, the yoked animals in this comparison received 25% fewer shocks than either of the avoidance-escape groups). The size of this difference (even ignoring the difference in shock frequency) tells us that the psychological characteristics of the stressful situation—the predictability, avoidability, and escapability of shock—primarily determined how pathological the stress situation was, not whether the animal was exposed to the stressor. I have noted this observation before (Weiss, 1968a, 1968b, 1970); initially, it was sur-
prising but it has proved to be a consistent feature of the results.

In regard to the other measures, the amount of body weight lost during the stress session by the various groups showed a pattern roughly comparable to that seen for stomach ulceration. Significant differences between avoidance-escape and yoked animals, with yoked animals losing more weight than avoidance-escape animals, appeared in the progressive-signal and no-signal conditions, although this difference did not reach significance in the signal condition.

For plasma corticosterone levels, the variation between individual rats was so large that this measure did not differentiate the groups. This variation, however, makes the steroid measure a good one for correlational analysis, and a correlation between steroid level and ulceration was observed which is of particular interest. Administration of exogenous steroids, both in humans and in rats, often leads to gastric ulceration, so that steroids are thought to be involved in the causal sequence by which gastric ulcerations develops (Roberts & Nezamis, 1964; Spiro & Milles, 1960). However, when exogenous steroid is given, the quantity is often so large, the introduction of steroid into circulation is so abrupt, etc., that we wish to know whether steroids secreted normally by the adrenal cortex play a role in the ulcerogenic process. Results in the present experiment showed that very high endogenously produced steroid levels were accompanied by severe gastric ulceration; this lends support to the possibility that steroids, in quantities that the animal is capable of secreting, may contribute to the production of ulcers.

A Theory to Explain How Coping Behavior Affects Ulcer Development

While a number of significant conclusions are clearly evident from the present results, puzzling aspects also remain. For example, why was the difference between avoidance-escape and yoked subjects consistently larger in the progressive-signal condition than it was in either of the other signal conditions? Based on data from the present experiment, I have been able to generate a theory which attempts to answer this and other questions relating to how coping behavior regulates the development of gastric ulceration in stressful situations. The derivation of the hypotheses will not be presented here; I shall simply state the theory and show how it conforms to the present results.

Stress ulceration is said to be a function of two variables: the number of coping attempts an animal makes, and the amount of appropriate feedback which these coping attempts produce. Figure 8 shows how these variables interact. On the left side of the solid line is represented the relationship between the first variable, number of coping attempts, and ulcerogenie (ulcer-producing) stress. When an animal is presented with a stressor, or stimuli associated (by contiguity) with the stressor, the animal will emit coping attempts which we measure as responses. The number of responses emitted and the amount of ulcerogenic stress directly covary; that is, the more responses we observe, the more likely the animal is to develop ulcers. Hence, the first proposition is that ulceration tends to increase monotonically as the number of responses, or coping attempts, increases.

The theory states, however, that expression of the foregoing relationship is completely dependent on a second variable—the consequences of coping attempts or, in op-
Fig. 9. At top (a) is shown the three-dimensional figure which describes the proposed relationship between responses, feedback, and ulceration. This relationship is a plane which shows how the two independent variables, responses and feedback, are related to the dependent variable, ulceration. At bottom (b) is shown how this plane is used. Where a hypothetical number of responses and amount of feedback intersect, the amount of ulceration is determined by the height of the plane above this point. (For ease of reading this figure, responses and feedback are labeled across the axes in the foreground. These labels are customarily placed along the axes in the background which are parallel to the ones bearing the labels. It therefore should be noted that feedback designations apply to the axis from Point A to the intersection of the three axes, and response designations apply to the axis from Point B to the intersection.)

In rational terms, the stimulus feedback from responses. The effect of this variable is shown on the right side of the solid line in Figure 8. If responses immediately produce stimuli that are not associated with the stressor, ulcerogenic stress will not occur. If, on the other hand, responses fail to produce such stimuli, then ulcerogenic stress will occur. Stimuli that are not associated with the stressor and that follow a response are called relevant feedback, since their occurrence is said to negate ulcerogenic stress. Thus, the more the relevant feedback, i.e., the more responses produce stimuli that are not associated with the stressor, the less the ulceration. The second proposition is, therefore, that ulceration tends to decrease monotonically as the amount of relevant feedback from coping attempts increases.

Combining these two propositions generates a function (a plane) such as is shown in Figure 9a. Figure 9b shows how, given the number of responses which an animal makes and the amount of relevant feedback it experiences from these responses, we can predict the amount of ulceration which will develop. Where number of responses and amount of feedback intersect, we simply project upward until we reach the plane; the height of this point represents the amount of ulceration which occurs.

This theory generates some interesting predictions. First, if an animal does not make coping attempts, it will not ulcerate regardless of what the feedback circumstances are. (See in Figure 9 that at all feedback values intersecting with “zero” responses, the plane shows no elevation.) Also, if relevant feedback is maximally high, an animal will not ulcerate regardless of how many responses it makes. (See in Figure 9 that at all response values intersecting with maximally high feedback, the and amount of feedback intersect, the amount of ulceration is determined by the height of the plane above this point. (For ease of reading this figure, responses and feedback are labeled across the axes in the foreground. These labels are customarily placed along the axes in the background which are parallel to the ones bearing the labels. It therefore should be noted that feedback designations apply to the axis from Point A to the intersection of the three axes, and response designations apply to the axis from Point B to the intersection.)
As number of responses increases and amount of feedback decreases, the point where these quantities intersect moves closer and closer to the intersection of the three axes, above which the plane progressively rises higher, denoting that ulceration is expected to become progressively more severe.

To apply this framework, it is necessary to keep clearly in mind what is meant by relevant feedback. The principle to be remembered is that relevant feedback consists of stimuli which immediately follow a response. The amount of relevant feedback is the extent to which a response produces stimuli that are not associated with the stressor. To avoid the stressor is not relevant feedback; in fact, more relevant feedback will occur from escape responses than from many types of avoidance responses. For example, in the present experiment the stimulus event of shock termination is further removed in time from the onset of the shock (i.e., less associated with the stressor) than is any other external stimulus in the environment (see Figure 2b). Moreover, shock termination is a very large change in the external stimulus situation and is, therefore, an extremely conspicuous event. These factors make shock termination excellent feedback, and this results from every escape response. In contrast, consider the feedback from avoidance responses in the no-signal condition. These responses postpone shock, thus producing kinesthetic and proprioceptive stimuli from responding which are always at least 200 sec. removed from the onset of shock (good feedback), but such responses produce no change at all in the external stimulus situation; hence, the amount of feedback from this type of avoidance response is considerably less than that of an escape response even though it avoids the stressor.

Figure 10 shows the present results in relation to the framework I have suggested. One can fix the position of any group with regard to the two important variables (responses and feedback) since the responding of each group was directly measured and the amount of feedback in each condition can be ascertained, which is done as follows: The best response feedback occurred for avoidance-escape animals in the progressive-signal condition. In this case, any response made more than 30 sec. after shock terminated a tone of some sort and immediately produced a stimulus condition (silence) which was not closely associated with the onset of shock. The only responses in this condition that failed to produce relevant feedback via external stimulus change were those that occurred within the first 30 sec. after shock. Avoidance-escape animals in the signal condition experienced less feedback than this since responses made before the beep produced no external feedback event in this condition. Nevertheless, feedback in the signal condition was quite good; relevant feedback from external stimuli did arise from responses which terminated the beep signal and, moreover, most animals in this condition responded to terminate shock, which provided excellent feedback as explained in the previous paragraph. The poorest feedback for avoidance-escape animals occurred in the no-signal condition. In this case, only escape responses provided substantial relevant feedback since responses prior to shock produced no external feedback, as explained in the previous paragraph. As a result, most of the responses made in the no-signal condition produced rather low feedback. Turning to the yoked animals, their responses, by definition, had no effect on external stimuli and so could not produce any stimuli consistently unrelated to the stressor; relevant response feedback for all such groups is zero. In Figure 10, all groups lie along the appropriate feedback coordinate at points corresponding to the amount of responding which they showed. At these points, the amount of observed ulceration is indicated by the height of each bar. The correspondence of these values with the theoretical function can be assessed by comparing their fit with the function in Figure 9. We can now see why, for example, the difference between avoidance-escape and yoked animals was so large in the progressive-signal condition, for animals in this condition made a substantial number of responses, with very good feedback occurring for avoidance-escape sub-
One of the most significant aspects of the theory proposed is that it does away with any qualitative distinction between animals which can avoid and escape shock and animals in contrast to the zero feedback for yoked subjects.\textsuperscript{5}

\textsuperscript{5}It is important to note that the small amount of ulceration which developed in nonshock control animals is not an exception to the theory set forth above but is also explained by using the same principles. A minimum stress condition was imposed on all subjects, including nonshock controls, since all subjects were restrained in the apparatus for 48 hr. without food. Any attempt that a subject made to get out of this stressful situation necessarily produced zero relevant feedback because no response ever produced escape from the chamber (i.e., no response produced any stimuli that were not associated with the chamber). Since attempts to escape from the apparatus produce zero feedback, simply being in the experimental situation is, according to the proposed theory, potentially ulcerogenic, and subjects will ulcerate in accordance with the number of escape attempts emitted. It was found, in fact, that the wheel-turning behavior of nonshock control subjects, which would reflect escape attempts, correlated with the amount of ulceration these subjects developed ($r = .66$). Thus, the ulceration of nonshock animals can be seen to develop as a function of coping attempts for which feedback is low, and consequently fits into the framework presented above. If we examine Figure 9, it is equally evident why the ulceration of nonshock groups was quite mild since, in the absence of the major stressor of electric shock, the number of responses emitted by these subjects was very low.

FIG. 10. The figure shows the results obtained in the present experiment in relation to the proposed theory. For each group which received shock, the amount of ulceration (height of bar) is shown at the point where responding and feedback for that group intersect.

One of the most significant aspects of the theory proposed is that it does away with any qualitative distinction between animals which can avoid and escape shock and animals in contrast to the zero feedback for yoked subjects.\textsuperscript{5}

\textsuperscript{5}It is important to note that the small amount of ulceration which developed in nonshock control animals is not an exception to the theory set forth above but is also explained by using the same principles. A minimum stress condition was imposed on all subjects, including nonshock controls, since all subjects were restrained in the apparatus for 48 hr. without food. Any attempt that a subject made to get out of this stressful situation necessarily produced zero relevant feedback because no response ever produced escape from the chamber (i.e., no response produced any stimuli that were not associated with the chamber). Since attempts to escape from the apparatus produce zero feedback, simply being in the experimental situation is, according to the proposed theory, potentially ulcerogenic, and subjects will ulcerate in accordance with the number of escape attempts emitted. It was found, in fact, that the wheel-turning behavior of nonshock control subjects, which would reflect escape attempts, correlated with the amount of ulceration these subjects developed ($r = .66$). Thus, the ulceration of nonshock animals can be seen to develop as a function of coping attempts for which feedback is low, and consequently fits into the framework presented above. If we examine Figure 9, it is equally evident why the ulceration of nonshock groups was quite mild since, in the absence of the major stressor of electric shock, the number of responses emitted by these subjects was very low.
mals which are helpless; the difference between such conditions is expressed quantitatively. If we consider the two dimensions which are functionally related to ulceration (responding and feedback), we see that avoidance-escape and yoked groups differ quantitatively with respect to both—these groups differ in the amount of responses they emit and in the amount of relevant feedback these responses produce. Thus, we can incorporate both avoidance-escape and yoked (helpless) conditions into a common schema, which we see done in Figure 10. The primary distinction between an avoidance-escape condition and a yoked condition lies along the feedback continuum; for yoked, or helpless, animals, relevant feedback for responding is zero, while for avoidance-escape animals, feedback occurs in some amount greater than zero depending upon the stimulus characteristics of the situation. This difference explains why animals which have control over a stressor generally ulcerate less than do helpless animals: Animals which have control generally receive a considerably greater amount of relevant feedback for their coping attempts than do helpless animals. Thus, the value of control for ameliorating ulcerogenic stress is said to lie essentially in the ability to produce relevant feedback from responses. Using this approach, we can analyze a wide variety of circumstances and predict their effects, which has been done in generating further experiments (Weiss, 1971a, 1971b).

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