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AMOUNT OF RESPONSE-PRODUCED CHANGE IN THE CS AND AVOIDANCE LEARNING[1]

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In discrete-trial avoidance conditioning to an external warning signal, the level of conditioning depended upon how much immediate change in the CS was effected by responding. The greater the change, the better the conditioning; this was interpreted in terms of the amount of reward for avoidance. A 2nd experiment showed that even when the response did not remove the warning signal, the occurrence of an additional, "safety" signal after the response improved level of conditioning. A 3rd experiment showed that a critical variable controlling level of conditioning was the amount of change in the stimulus following the response and that direction of the change, whether toward or away from the between-trials stimulus, was unimportant.

Our task here is to specify what corresponds to an "amount of reward" variable in avoidance conditioning. With a discrete trial procedure, the external warning signal (CS) preceding shock acquires aversive properties. Avoidance responses presumably are reinforced because they are instrumental in escaping or terminating this conditioned aversive stimulus. It seem reasonable to suppose that the amount of reward for the instrumental response will depend upon the amount of change in the stimulating conditions following the response.

The intratrial paradigm for our shuttlebox avoidance experiment is as follows: the CS is the onset of a tone at a particular loudness; following the shuttle response (whether it is an escape or avoidance), the intensity of the tone is reduced immediately by a fraction, and then, after a longer period of time, the tone goes off entirely. The experimental variable is the percentage reduction in CS intensity immediately following the response, and it is completely analogous in its role to the percentage shock-reduction in a shock-escape learning situation (cf. Bower, Fowler, & Trapold, 1959; Campbell & Kraeling, 1953).

The proposed law is that variations in this percentage of reduction in CS intensity will result in graded variations in avoidance conditioning. On theoretical grounds, this relationship is expected to obtain for several reasons which depend upon the similarity of the cues prevailing at the outset of the trial before the response (called pre-R cues) to those cues prevailing after the instrumental response occurs (post-R cues). On a Guthrian interpretation (1935), reward is identified with the amount of change in the stimulus following R, thus reducing the transfer to pre-R cues of incompatible responses (crouching, relaxing, etc.) learned via contiguity with post-R cues. Alternatively, the Miller-Mowrer approach (Miller, 1951; Mowrer, 1959) might suppose that a fear response would be conditioned to pre-R cues; then the amount of fear reduction (and reinforcement) following the instrumental response would depend upon the distance on a generalization gradient between the pre-R and post-R cues evoking the fear response. Both ideas imply the proposed law and it is doubtful whether they can be distinguished in this context. The empirical question was whether the proposed law would be confirmed in the following experiment.

EXPERIMENT 1

Method

Subjects. The *S*s were 46 albino rats of the Slonacker strain bred in the departmental colony. There were approximately half males and half females, 90–130 days old when tested. The single experimental session with each rat required about 60 min.; otherwise, *S*s lived in group cages with free access to food and water.

Apparatus. The apparatus was a two compart-

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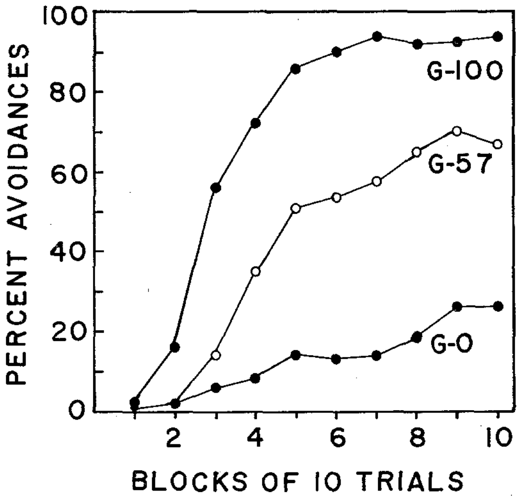

FIG. 1. Group mean percentage of avoidance responses in 10-trial blocks. (For Group 100, the CS terminates immediately after R; for Group 57, the CS reduces 57% after R and then goes off after 10 sec.; for Group 0, the CS remains unaltered before going off 10 sec. after R.)

ment shuttle box with a grid floor throughout. One compartment was painted black, the other white. Each compartment was 16 × 6¼ × 12½ in., with a small barrier separating the compartments. Shock was delivered to the floor of the compartment occupied by *S* via grid bars consisting of ⅛-in. welding rods spaced ½ in. apart. To provide shock, the 330-v. output of a transformer was fed into a potentiometer, and thence through a ¼-meg. ohm resistor in series with the grid bars. Shock levels were determined individually for each *S* to produce a quick jump; the usual level was 0.5–1 ma.

The external warning signal was 1,000-cps tone delivered simultaneously through two loudspeakers, one housed behind each end of the two compartments. Each 6 × 3 in. oval speaker was mounted behind a multi-holed wooden baffle with 4 in. from the floor to the center of the speaker. Sound pressure levels were measured from the C scale of a 1551-B General Radio Company sound level meter. Readings from several locations inside the two compartments were taken to check for local variations. The onset of the CS tone registered 89 db. ± 2; the intensity following "partial reduction" measured 78 db. ± 1. The ambient noise level inside the box with no tones was 72 db. ± 2. Considering the useable range in intensities to be 89-72 = 17 db., the partial intensity reduction covered 89-78/17 or approximately 57% of the range.

At the start of a trial, the tone was turned on, a clock started to record latency, and a timer began a 5-sec. interval. If *S* ran into the other compartment before 5 sec. had elapsed, he avoided shock and his response stopped the clock. If *S* failed to respond within 5 sec., shock came on and continued until he escaped to the other compartment.

Procedure. Each *S* received 100 massed trials in one continuous session. The treatment variable is the percentage reduction in tone intensity immediately following the response (escape or avoidance). Group 100 ($N = 18$) had the tone terminated immediately after R. Group 0 ($N = 18$) had no reduction immediately following R; the tone continued at 89 db. for 10 sec. before terminating. Group 57 ($N = 10$) had an immediate reduction of 57% in the tone intensity following R; the tone continued at 78 db. for 10 sec. before it terminated. The intertrial interval averaged 30 sec. with a range of 15–45 sec.

Results

The main results are shown in Figure 1, which gives the average percentage avoidance responses in blocks of 10 trials. The groups diverge with training and always are ordered in the predicted direction. The mean numbers of avoidances over the 100 trials were 68, 43, and 12 for Groups 100, 57, and 0, respectively. Each mean differs from its adjacent member at beyond the .001 level ($t = 3.55$ and 4.08 for the comparisons involving Group 57). Thus, the proposed law has been confirmed, at least for the 100-trial series involved in this experiment. Avoidance conditioning with an external warning signal is an increasing function of the amount of change (intensity reduction in this case) in the signal immediately following the response.

The reader may have noted that our 100% and 0% conditions can be described as 0- and 10-sec. delayed reward (CS termination). The results for these two groups are comparable to those reported by Kamin (1957) who studied the delay gradient. After completing this research, the authors found that Denny, Koons, and Mason (1959) had studied the effect of similarity of pre-R to post-R cues upon rate of extinction of an avoidance habit. They reported faster extinction in rats the more similar was the jump-out box (post-R) to the shock box (pre-R). They interpreted their result in terms similar to the Guthrian idea used here.

It might be alleged that the intensity of the CS is sufficient to be innately aversive (Campbell, 1955), and that our treatment differences merely parallel those to be expected by greater reduction in this stimulus irrespective of its pairing with shock. To assess the possible contribution of this confounded variable, three naive rats were tested to see whether in this particular situation escape performance (without shock) could be motivated and reinforced by onset and termination of the 89-db. tone used as the CS in the prior study. In 30 trials, one *S* made 0, one made 2, and one made 4 crossings during the 5-sec. tone, frequencies which are about what would be expected on the basis of random exploration. By this assessment, the confounded variable seems not to have been particularly potent in these circumstances.

Experiment 2

The CS in the discrete-trial avoidance situation would appear to serve two functions: the first, that of a warning signal to cue off avoidance; the second, that of an "all's safe" signal when it terminates. In most avoidance experiments, these two functions are assigned to the onset and offset, respectively, of the warning signal. But our analysis suggests that this is only a convenient, not a necessary, arrangement, since any two discriminable stimulus situations would serve equally well in these roles. The purpose of our second experiment was to separate these two functions, having each correlated with different stimuli. Again the onset of an 89-db. tone served as a warning signal for avoidance. For *S*s in the newly introduced condition (Group L), when the response occurred, a light came on for 15 sec. The tone continued for 8 sec. after the response and terminated 7 sec. before the light. In colloquial terms, the purpose of the light was to inform *S* that he had made the correct response and that he was now safe from shock. In Guthrian terms, the light serves to reduce transfer of competing behavior from post-R to pre-R cues. In any event, we would expect the addition of a "safety" cue following R to facilitate acquisition of avoidance.

Method

Subjects. Forty-nine new rats from the same source, approximately half males and half females, served as *S*s. Each was run in a single 150-min. session, being given 100 trials.

Procedure. Three groups were run. Group 100 and Group 0, with 13 and 18 *S*s each, were essentially replications of those in Experiment 1. The procedure for the 18 *S*s in Group L was identical to that of Group 0 (post-R tone for 8 sec.) except that a light was turned on for 15 sec. after R occurred. The lights were 15-w. bulbs mounted on the rear wall in each compartment; only the light in the "safe" compartment (where *S* was after R) was turned on. The differences from Experiment 1 were as follows: (*a*) a different *E* ran *S*s; (*b*) the intertrial interval was longer, averaging 75 sec. instead of the former 30 sec.; (*c*) the tone continued after R for 8 sec. (instead of 10 sec.) before terminating.

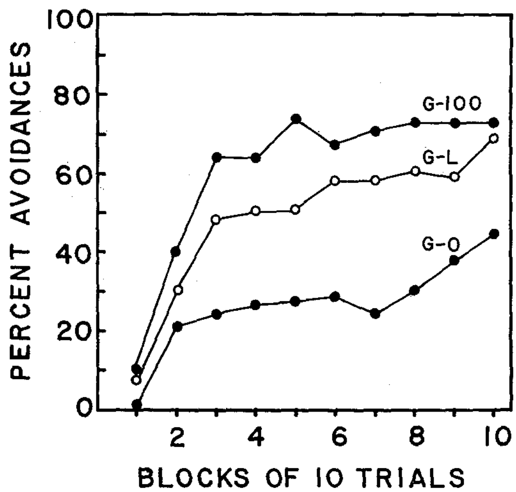

Fig. 2. Group mean percentage of avoidance responses in 10-trial blocks. (For Group 100, the tone terminates immediately after R; for Group 0, the tone terminates 8 sec. after R; for Group L, a light comes on for 15 sec. after R while the tone persists for 8 sec.)

Results

The main results are shown in Figure 2 in terms of average percentage of avoidance responses in blocks of 10 trials. The groups are in the expected order throughout. The difference in avoidance between Groups 100 and 0 was smaller than in Experiment 1. The mean number of avoidance responses over all 100 trials was 58, 49, and 27 for Groups 100, L, and 0. The L mean was significantly above that for Group 0 ($p < .01$) but was not significantly below that for Group 100 ($t = 1.46$, $df = 29$). We conclude that addition of a safety signal to the post-R cues facilitated learning of avoidance (i.e., Group L is superior to Group 0).

One interpretation of this effect is that the added light cue serves simply to reduce transfer of competing behavior from post-R to pre-R cues. A not incompatible alternative (Mowrer, 1959) is that the light becomes a conditioned signal for anxiety reduction or relief. If so, then one would expect *S*s to learn some new response to turn on the light if they are frightened but the old response to fear is prevented. We have done no systematic work on this particular question.

Experiment 3

Recalling the results of Experiment 1, better learning occurred with a greater change in the stimulus following the response. However, the change in that case was in a direction toward the between-trials stimulus (i.e., a reduction in intensity toward silence). But suppose that the between-trials stimulus (BTS) acts like a safety signal since silence is usually present and is never paired with shock. Then we might interpret the Experiment 1 results to read: more reward occurs the more the post-R cues return the CS towards the BTS for safety. Thus, the question arises, is it the pre-R to post-R cue change per se that is of sole importance for reward, or is it rather that a given change in the CS is reinforcing only when it is in a direction towards the BTS for safety? Guthrie might answer affirmatively to the first, and Mowrer to the second (return to safety cue is secondarily reinforcing), although these are only intuitive and not firm identifications.

To answer the empirical question, we shifted to a tone frequency (pitch) continuum to avoid the aversive loudness problem mentioned earlier, and set up an experiment using three tone generators. One tone was on continuously between trials; it was replaced by a second tone as the CS or warning signal; and the latter was replaced by a third tone for 10 sec. following the response. Thereafter, the BTS tone recurred. Four different conditions were studied, obtained by combining an increase or decrease in pitch as the CS with a post-R change in the CS toward or farther away from the BTS.

The different theoretical outcomes may be illustrated for the case in which the CS is an increase in pitch. For half of these *S*s the response immediately changes the tone back to the BTS; for the other *S*s, the response immediately causes the pitch to increase further, to a higher value that is maintained for 10 sec. before it is returned to the BTS. If the effective amount of change is the same in these two cases, then the one hypothesis leads us to expect equal reward and learning for the two groups. The alternative hypothesis would expect the first group to be superior; in fact, assuming that fear is conditioned to an increase in pitch, rather than to the specific frequency paired with shock, a further increase after the response might punish avoidance responses in the second group, or at least produce only negligible reinforcement for the response.

Method

Subjects. The *S*s were 40 male Wistar rats, 90 days old, purchased from a local vendor. They

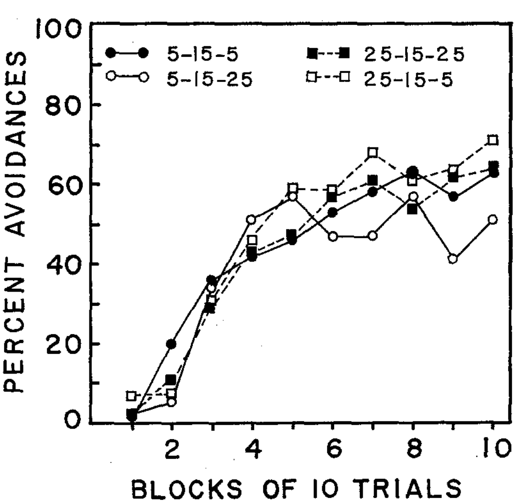

Fig. 3. Group mean percentage of avoidance responses in 10-trial blocks. (For all *S*s the trial stimulus is a tone of 1,500 cps. and the response changes the tone by 1,000 cps. The groups differ in the between-trials tone and the immediate post-R tone.)

were maintained in group cages on ad-lib food and water. Ten *S*s were assigned in alternation to each of the four experimental conditions.

Procedure and design. The apparatus was the same as before except there were three separate tone generators. The tones, specified in hundreds of cycles per second, were 5, 15, and 25. An experimental condition may be specified by a triplet wherein the first number is the BTS, the second is the CS or trial stimulus, and the third number is the postresponse frequency which prevailed for 10 sec. after the response. Thereafter, the BTS was reinstated. In this notation, the four conditions studied were 5-15-5, 5-15-25, 25-15-25, and 25-15-5. For the first and third groups, the response (escape or avoidance) returned the CS to the BTS; for the second and fourth, the response produced a temporary value which was even more discrepant from the BTS. The absolute change from CS to immediate post-R frequency was 1,000 cps in all cases, and the trial stimulus was 1,500 cps in all cases.

Each *S* received 100 massed trials in one session with a mean intertrial interval of 30 sec., range of 20–40 sec. The shock level was comparable to that in Experiment 1. The CS-shock interval was 5 sec. If hurdle-crossing occurred before 5 sec., shock was omitted; otherwise, shock came on and *S* was forced to escape by crossing to the other compartment. In either event the post-R cue occurred immediately following the response.

Results

The principal results are shown in Figure 3 in terms of group average percentage avoidance responses in 10-trial blocks. The proficiency of learning under these conditions was moderate (around 60%), which means that ceiling effects do not contaminate the present comparison. It is clear from Figure 3 that there are no large differences among any of the groups. The mean avoidance responses over all 100 trials for Groups 5-15-5, 5-15-25, 25-15-25, and 25-15-5 were 44, 39, 43, and 47, respectively. No group differences were significant. Thus, as far as this experiment goes, we may conclude that it was the amount of change that is important for reward and that the direction of that change, whether toward or away from the BTS, was relatively inconsequential.

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