

*POSITIVE CONDITIONED SUPPRESSION: CONDITIONED  
SUPPRESSION USING POSITIVE REINFORCERS  
AS THE UNCONDITIONED STIMULI<sup>1</sup>*

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Research has revealed the phenomenon of conditioned suppression in which the rate of responding is reduced during a stimulus that is paired with noncontingent shock. The present study replicated this procedure, but used noncontingent positive reinforcers instead of the aversive shock. The lever-pressing responses of rats were reinforced with food or water. While the rats were responding, a stimulus was occasionally presented and paired with the delivery of a noncontingent positive reinforcer, which was either food, water, or brain stimulation for different rats. The result was a reduction in the rate of responding during the conditioned stimulus. This finding shows that conditioned suppression occurs during a signal for reinforcing as well as aversive stimuli.

Estes and Skinner (1941) discovered the phenomenon, now known as conditioned suppression or conditioned anxiety. A baseline of lever-pressing responses was established by an intermittent schedule of food reinforcement; at infrequent intervals the rats were given an aversive shock that was immediately preceded by a neutral stimulus. The subsequent reduction in the rate of responding during the previously neutral stimulus supported their interpretation that anxiety was produced by the conditioned stimulus, as evidenced by the degree of disruption of ongoing operant responses. Later studies by many investigators, including Hunt and Brady (1955), Lyon (1964), Kamin, Brimer, and Black (1963), Stein, Sidman, and Brady (1958), Azrin (1956), Hendry and Van Toller (1965), Hake and Azrin (1965), also found a reduction in the rate of operant responding during a preshock stimulus. The shock has generally been designated as an unconditioned stimulus (UCS), the neutral stimulus as a conditioned stimulus (CS), and the pairing of the two events as an example of a classical conditioning procedure.

The anxiety interpretation of Estes and Skinner states that the reduction in the rate of responding during the conditioned stimulus is dependent upon that stimulus being paired with a "disturbing" or aversive event. Indeed, the reduction in response rate during the conditioned stimulus has been considered (Ferster and Skinner, p. 723, 1957) as a defining characteristic of an aversive stimulus. Another possible interpretation is that the reduction in response rate results from a general emotional state during presentation of a stimulus that is paired with any strong reinforcer, whether the reinforcer is positive or negative. These interpretations lead to different predictions about the possible effect of different types of unconditioned stimuli. Since the anxiety interpretation attributes the reduction in response rate to the degree of aversiveness of the unconditioned stimulus, this interpretation has led to the expectation that an unconditioned stimulus that was a positive reinforcer should produce an effect opposite to reduction, *i.e.*, an increase in response rate because of an "elation" or "joy" effect, as has been suggested by many including Millenson (1967), Rescorla and Solomon (1967), and Herrnstein and Morse (1957). The general emotional state interpretation, not being dependent on the qualitative aspect of the noncontingent stimulus, predicts that a positive reinforcer should produce suppression. Millenson (1967) has discussed both interpretations and the absence of definitive evidence in sup-

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port of one over the other. The present study evaluated these interpretations by replicating the main features of the Estes and Skinner procedure but using food, water, or intracranial stimulation instead of aversive shock as the noncontingent stimulus. Intracranial stimulation was selected as one of the reinforcers because its mode of delivery is similar to pain-shock in that no consummatory response is required.

### METHOD

The subjects were 18 experimentally naive male rats, 90 to 120 days old, of the Holtzman Sprague-Dawley strain.

#### *Apparatus*

Two chambers were used. One, about 11 by 9 by 9 in. high, was used for all but the two rats given intracranial stimulation. A response lever (Lehigh Valley Electronics Rat Lever #1352) was mounted 2 in. from the floor. A tray for delivery of food was located 0.25 in. to the right of the lever and a tray for water was 0.25 in. to the left. A downward force of 15 g on the lever defined a response, each of which received brief feedback in the form of a 100-msec interruption of the overhead lighting. The CS was a relay click that occurred six times per second.

A second larger chamber, 13 by 12 by 14 in. high, was used for the two rats given intracranial stimulation. It was similar to the first chamber except that it had no water delivery tray; the CS was a 10-Hz blinking red light located 5 in. above the response lever; a relay click provided the response feedback.

#### *Procedure*

The rats were divided into two groups. The eight in the water group received 0.1 cc of water as the contingent reinforcer for lever pressing and the 10 rats in the food group received one 45-mg food pellet as the contingent reinforcer. A buzzer sound accompanied the delivery of food; a distinctively different 500-Hz pure tone accompanied delivery of water. After about seven shaping and conditioning sessions for all rats, the lever-press response was being reinforced according to a 1-min variable-interval schedule of reinforcement during daily 2-hr sessions (1.5 hr for two rats in the food group). The CS was then

presented for 10 sec at irregular intervals averaging 6 min between presentations (4 min for two of the rats) for a minimum of three and a maximum of six sessions. The rats were then subdivided further into five groups. Of the eight rats that were receiving water as the contingent reinforcer, two were given 0.5 cc of water also as the noncontingent stimulus (Water-Water Group), and six were given five pellets of food (Water-Food Group). Of the 10 rats that received food as the contingent reinforcer, three received five pellets of food as the noncontingent stimulus (Food-Food Group), five received 0.5 cc of water (Food-Water Group), and two received intracranial stimulation (Food-ICS Group). The noncontingent stimulus was delivered at the termination of the conditioned stimulus for 15 sessions (10 for the Food-ICS Group). The CS was 10 sec in duration plus the duration required for delivery of the noncontingent stimulus. The contingent reinforcer for lever pressing continued to be delivered according to the 1-min variable-interval schedule. Finally, the noncontingent stimulus was discontinued for 15 sessions (five sessions for the Food-ICS Group) during which the contingent reinforcer and the 10-sec CS continued to be presented.

For the rats that were not receiving water, whether as a contingent or noncontingent stimulus (Food-Food Group and Food-ICS Group), water was freely available in the experimental chamber during the session. Similarly, food pellets were freely available in the chamber for the rats not receiving food as a contingent or noncontingent stimulus (Water-Water Group). For the Water-Food group, food was freely available during the sessions in which food was not experimentally scheduled; food deprivation was initiated the day before the noncontingent food was scheduled. Similarly, water was freely available for the Food-Water Group during those sessions in which water was not experimentally scheduled; water deprivation was initiated the day before the noncontingent water was scheduled. These maintenance procedures were necessary because food-deprived rats responded very little for food unless water was also given during that session. Similarly, water-deprived rats responded very little for water unless food was available during the session. When food was used as a contingent or noncontingent stim-

ulus the weight of the rat was reduced to 80% of free-feeding weight. When water was used, either as a contingent or noncontingent stimulus, the rat was restricted to 14 cc of water per day. The noncontingent food delivery was deliberately made greater than the contingent food (five pellets *vs* one pellet) to allow discrimination between them as different events. Similarly, the noncontingent water delivery was 0.5 cc, whereas the contingent water was 0.1 cc.

One week before their first session, the two rats in the Food-ICS Group had bipolar stainless steel electrodes implanted stereotaxically using a procedure similar to that described by Miller, Coons, Lewis, and Jensen (1961). The electrodes were 0.01-in. diameter covered with insulation except at the cross-sectioned tips. The waveform of the electrical stimulus was the same as that described by Valenstein and Meyers (1964): a 0.5-sec pulse train of 100-Hz biphasic rectangular pulses, each pulse having a duration of 0.2 msec with a 0.2-msec delay between positive and negative excursions. A pre-test was given to both rats, using a different response and different stimulus conditions, to determine the current intensity necessary to reinforce responding when the stimulation occurred at the same frequency of presentation as would be used in the experiment proper. A 0.5-sec pulse train of 0.095 ma for one rat and 0.065 ma for the other were found to reinforce a chain-pull response during a 10-sec white stimulus light, which was presented at irregular intervals averaging 4 min. Ten of these 0.5-sec pulse trains were delivered as the noncontingent stimulus during the experiment proper, each train following the previous one by 40 msec. The day after this experiment was completed, one rat was given a post-test in which it received the 10 pulse trains for the first chain-pull that occurred during a stimulus presented at irregular intervals averaging 4 min. The latency of chain-pulling averaged less than 2 sec for both rats in the pre-test and the one rat in the post-test. After the last session, the brain tissue was prepared and photographed according to the procedure described by Hutchinson and Renfrew (1967). Figure 1 shows that the electrodes were in the medial forebrain bundle just ventrolateral to the posterior hypothalamus for one rat and ventromedial to the medial lemniscus and dorsolateral to the ven-

tral tegmental nucleus for the other rat. Previous studies have reported positive reinforcing effects of electrical stimulation in or near these sites (Hawkins and Pliskoff, 1964; Valenstein and Meyers, 1964; and Valenstein, 1965).

RESULTS

Figure 2 shows responding during the CS relative to responding during the baseline use-

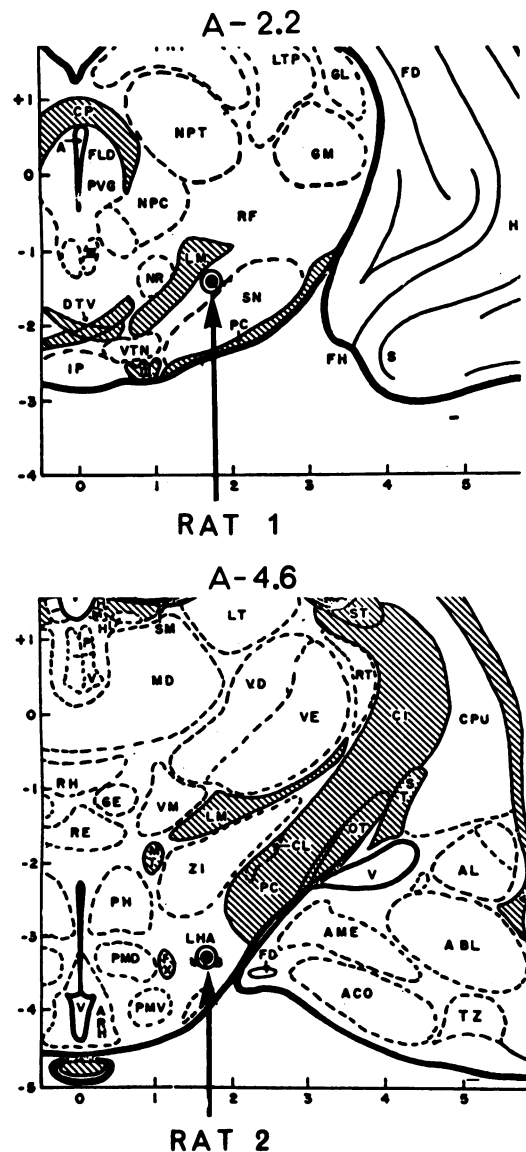


Fig. 1. Electrode placements for the two ICS subjects illustrated on frontal sections of the rat brain. The number above each section identifies the plate of the DeGroot (1963) rat stereotaxic atlas from which the sections were copied.

ing the ratio suggested by Annau and Kamin (1961) for measuring the degree of conditioned suppression. This ratio is equal to  $B/A+B$  where B is the number of responses during the 10-sec CS and A is the number during the 10-sec period preceding the CS. Hence, a ratio of 0.5 indicates no suppression; a ratio of 0.0 indicates complete suppression. For all five groups of rats, this suppression ratio was about 0.5 during the last three sessions before the noncontingent stimulus was presented. When the UCS was added, conditioned suppression occurred during the first or second session for all groups; the conditioned suppression continued during each day of UCS delivery for all groups except the Water-Water Group. When the UCS was discontinued, the suppression ratio increased on the first or second day when UCS was absent, eventually returning to the non-suppressed level of about 0.5 seen initially.

Table 1 shows the mean response rate during the pre-CS and the CS periods. For indi-

vidual rats, the rate was as low as 10 and as high as 103 responses per minute at the start of the study. The mean response rate during the CS decreased by about one-half when the UCS was added and increased three-fold when it was discontinued. On the other hand, the baseline pre-CS response rate remained about the same when the UCS was added but did increase by about one-half when it was eliminated. The higher response rates at the end of the study during both the CS and pre-CS probably reflect the general increase usually found during continued reinforcement under a variable-interval schedule (Ferster and Skinner, 1957). Taken together these data show a large reduction in the rate of responding during the CS superimposed on an upward drift of the baseline response rate. The data of Table 1 show that the suppression seen in Fig. 2 was primarily attributable to the reduction of response rate during the CS rather than to an increase in the rate of baseline responding.

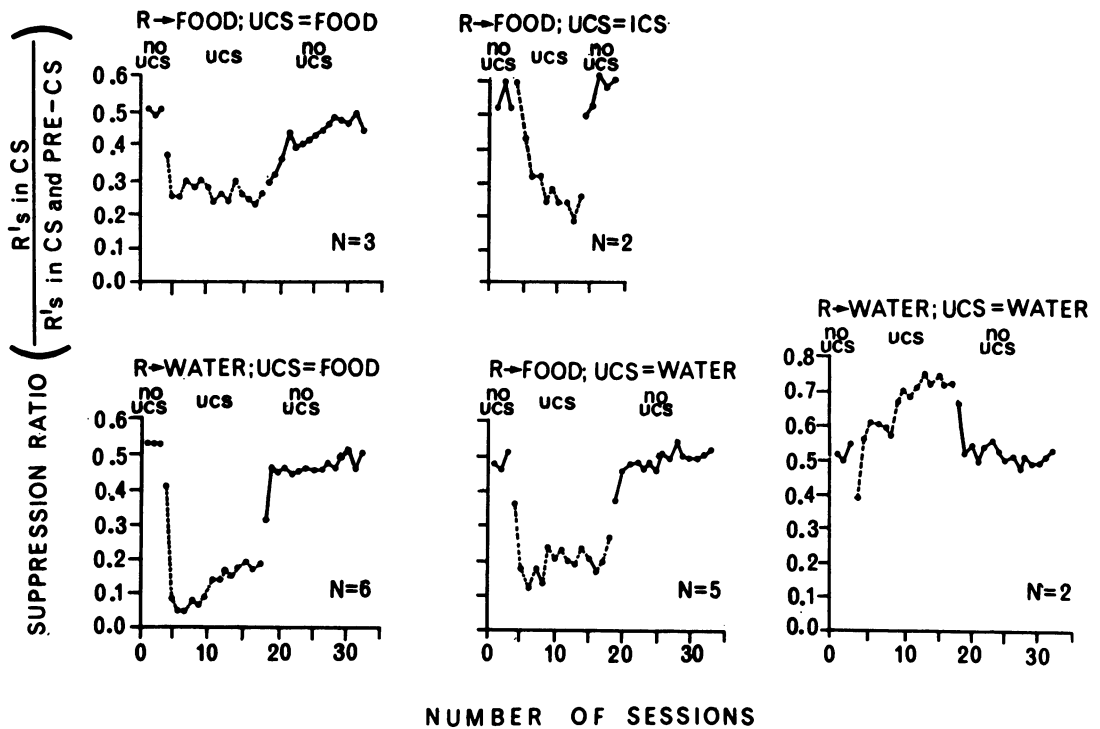


Fig. 2. Changes in the suppression ratio during a conditioned suppression procedure in which an unconditioned stimulus (UCS) was delivered automatically after 10 sec of conditioned stimulus (CS) presentation. Each graph is for a different group of rats. A suppression ratio of 0.0 shows complete suppression, 0.5 shows no suppression during the CS relative to the baseline. The designation above each graph describes the operant reinforcer delivered for the lever-pressing response (R), and also the nature of the UCS, one of which was intracranial stimulation (ICS). The initial "no UCS" period represents the last three sessions of that condition.

Table 1

Mean number of responses per minute for 18 rats during the Pre-CS and CS.

	<i>Noncontingent UCS</i>		
	<i>Absent (Three Sessions)</i>	<i>Present (Five Sessions)</i>	<i>Absent (Five Sessions)</i>
Pre-CS Period	56.4	54.0	76.8
CS Period	57.6	25.8	76.8

Analysis of the data for individual rats revealed that 15 of the 18 had suppression ratios of 0.02 to 0.40 calculated for the last five sessions of noncontingent stimulus presentation. Responding for six of these 15 rats was almost completely suppressed during the CS; the suppression ratios were less than 0.10. The two rats in the Water-Water Group (see Fig. 2) and one of the six in the Water-Food Group did not show response suppression; two showed slight response facilitation (0.60) and one showed substantial response facilitation (0.87). Each of these three rats had shown suppression during the first session in which the noncontingent stimulus was given; their suppression ratios were 0.35, 0.40, and 0.44 respectively for that session. A possible reason for the facilitation rather than suppression on subsequent days for these three rats is that adventitious reinforcement (Skinner, 1948) of some responses resulted from accidental correlations of the noncontingent stimulus with the lever press. To evaluate this interpretation, the two rats in the Water-Water Group that showed facilitation were given 23 additional sessions during which adventitious correlations were experimentally reduced by imposing a brief delay of 1.0 sec between the lever-press response and the noncontingent water delivery. The contingent water delivery continued to be given immediately after a lever press. For the rat that had shown the greatest facilitation, the mean suppression ratio for the last five days decreased from 0.87 to 0.41; for the other rat, which had shown only mild facilitation, the suppression ratio of 0.60 remained unchanged.

Gross observation of all rats during the CS revealed no pattern of competing responses. Some rats moved about rapidly, others moved only their head while still hovering above the response lever. Other rats seemed simply to "freeze" and others adopted no consistent pattern except to discontinue lever pressing.

## DISCUSSION

The present findings revealed that the rate of responding was reduced during a stimulus that was paired with a positive reinforcer. Several features of the study indicated that the findings have generality over a range of conditions. The suppression was not dependent on the use of a specific operant reinforcer for the baseline responses, since both food and water were used for different rats; nor was it dependent on a specific conditioned stimulus, since both a clicker and a blinking light were used; nor was it dependent on the rate of the baseline responses, since the rates were as low as 10 and as high as 100 per min; nor was it dependent on a specific type of noncontingent reinforcer, since food, water, and ICS were used. The magnitude of the effect could be large, as seen by the near-zero suppression ratio for six of the rats. The effect was durable as seen by the continued reduction each day for as long as the procedure was maintained. The non-suppressive effect of the conditioned stimulus alone was evidenced by the usual rate of response when the unconditioned stimulus was absent. Especially important, almost all of the animals showed the effect. These findings indicate that the response reduction during a stimulus preceding a noncontingent positive reinforcer is substantial and general to a number of procedural variations.

The present results were similar in several ways to the findings of studies of conditioned suppression (see especially, Annau and Kamin, 1961) that have used aversive shock as the noncontingent reinforcer. The reduction in response rate occurred within one or two sessions, it was durable over continued sessions, the rate recovered rapidly when the noncontingent event was discontinued and the reduction was restricted largely to the CS period. Further evidence of comparability with the shock procedure must await subsequent studies that manipulate variables common to both procedures. At present, suppression during the aversive shock procedure seems best considered as one instance of the phenomenon, rather than as a model, since several types of positive reinforcers produced the suppression phenomenon, whereas only one type of negative reinforcer (shock) has produced it (Leitenberg, 1965). The phenomenon can be differentiated by designating it as negative conditioned sup-

pression when a negative reinforcer such as shock is used, but as positive conditioned suppression when a positive reinforcer is used.

The findings failed to support the interpretation that competing behavior caused the suppression. First, gross observation failed to reveal any obvious competing type of activity, unless not responding is considered a competing reaction to responding. Secondly, the response lever was located so close to the food and water tray that the rats need not, and did not, leave the location of the lever to receive the noncontingent food and water deliveries. Thirdly, the intracranial stimulation required no consummatory response, nor did it elicit any strong unconditioned reactions. For the above reasons, the suppression cannot be accounted for by an appeal to incompatible conditioned reactions. It is still possible, and probable, that the interference is associated with autonomic changes during the CS such as has been found for cardiac changes (Stebbins and Smith, 1964; deToledo and Black, 1966) when shock has been used in the conditioned suppression procedure. Similarly, consistent patterns of salivation have been recorded during operant reinforcement by food (Shapiro, 1961, 1962; Kintsch and Witte, 1962). Although the autonomic changes have not been causally related to the operant changes (see review by Rescorla and Solomon, 1967), both changes may be the product of an underlying emotional state of heightened preparedness. This interpretation is similar to that made by Estes and Skinner (1941), except that the emotional state need not be negative.

The substantial facilitation, rather than suppression, that was found for one of the rats seemed to be the result of superstitious conditioning (Skinner, 1948) as evidenced by the suppression that resulted when adventitious correlations were prevented between the lever press and the noncontingent stimulus. Perhaps this preventive measure would have eliminated the slight facilitation shown by the other two rats had this feature been present at the start of the study. Additional evidence that facilitation was caused by a superstition was that facilitation occurred only after an initial suppression; all 18 subjects showed substantial suppression during at least the first or second day of pairing the conditioned stimulus with the noncontingent stimulus. Also, two of the three rats that showed facilitation

were receiving the same event as a noncontingent stimulus that was being given as a contingent reinforcer. This similarity would seem especially likely to produce a superstition.

The present results can be considered an example of respondent-operant interaction, a phenomenon which has received extensive theoretical attention by most dual-process learning theories (Skinner, 1938; Mowrer, 1960; Brown, 1961; Miller, 1951; and see review by Rescorla and Solomon, 1967). Several studies have found that Pavlovian pairing of a CS with food has resulted in an increase in the rate of food-reinforced responding when the CS was presented (Estes, 1948; Herrnstein and Morse, 1957; Morse and Skinner, 1958; Bower and Grusec, 1964). This increase, rather than decrease, seems to be accounted for by consideration of the similarity between the contingent and noncontingent reinforcer. The present study eliminated the possibility of similarity in the Food-Water, Water-Food, and Food-ICS procedure by making the contingent and noncontingent reinforcers qualitatively different from each other. Quantitative dissimilarity was attempted in the present Food-Food and Water-Water group by making the noncontingent event larger than the contingent event. In contrast, the noncontingent reinforcer and contingent reinforcer seen in previous studies were qualitatively and quantitatively identical and could thereby be expected to interact on the basis of discriminative rather than reinforcing properties. Adventitious reinforcement may also have been a factor in the Herrnstein and Morse (1957) study, as it was in the present study. In agreement with the present interpretation, Pliskoff (1961, 1963) found that food-reinforced responses were suppressed during a stimulus that preceded a period of high frequency reinforcement. As in the present study, the contingent and noncontingent events were at least quantitatively different.

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