Compound testing of individually conditioned stimuli as an index of excitatory and inhibitory properties

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In a classical conditioned-suppression procedure, two CS+s, when presented in compound, produced more suppression than either alone; a CS+ and a CS-, when presented in compound, produced less suppression than the CS+ alone; and a compound consisting of CS+ and a "neutral" CS° produced suppression which did not differ from CS+ alone. The differential effects of the compounds permit one to measure excitatory or inhibitory properties of a CS.

In this research we were interested in the effects of compound presentations of two classically conditioned stimuli (CSs) after training procedures in which either (a) both had been paired with an unconditioned stimulus (US), or (b) one stimulus (CS+) was paired with the US while the second stimulus (CS-) was not. We hoped that a comparison of these compounds would permit us to assess the excitatory and inhibitory properties of their elements in a manner similar to that employed by Cornell & Strub (1965) for discriminative stimuli in operant conditioning situations.

EXPERIMENT 1

Each of two CSs was separately paired with a shock US while rats pressed a lever for food reinforcement. Suppression of bar pressing produced by each CS and by the compound of both CSs was then measured. Since any enhanced suppression to the compound could not be observed when suppression to the individual CSs was complete, compound tests were made in early acquisition and early extinction when some responding to each of the CSs occurred.

Subjects

The Ss were 18 male hooded rats, maintained at 75% of their ad lib body weights throughout the experiment.

Apparatus

The apparatus consisted of standard Skinner boxes, individually housed in sound-reducing chambers. The two stimuli employed as CSs were darkness (D), produced by turning off the 6-W houselight, and a 70-dB white noise (N). The shock was obtained at the 1.0-mA setting on Grason-Stadler shock generators.

Procedure

The Ss received five daily 2-h sessions of bar-press training in which food pellets were delivered on a VI 3-min schedule. Two pretest trials of each of N, D, and the N/D compound were given on the following session. Two days of conditioning followed. On each day, two 90-sec presentations of N and two of D were scheduled at randomly selected intervals. Shock was programmed during the last .5 sec of each CS. Order of presentation of the CSs was counterbalanced.

The data were described in terms of suppression ratios according to the formula $B/(A+B)$, in which A = number of responses during the 90 sec immediately preceding CS onset and B = the number of responses recorded in the presence of the 90-sec CS.

Compound tests were made at two points: (1) An unreinforced test trial was scheduled for all Ss at the end of the first conditioning session. Six Ss were tested with N, six with D, and six with the N/D compound. (2) Compound tests were scheduled for 13 rats following the satisfaction of an extinction criterion, defined as follows: for each S, unreinforced presentations of one CS were repeated at 5-min intervals until the suppression ratio reached .20 or above. The other CS was then presented repeatedly until the .20 criterion was satisfied, whereupon the first stimulus was tested again to insure that it still exceeded the .20 criterion. The compound was then presented. Each of the individual stimuli was presented once more following the compound test.

Results

The results for both acquisition and extinction are presented in the upper half of Fig. 1. In acquisition, all six Ss tested with the compound showed greater suppression to the compound than to either of the preceding single-stimulus trials. This pattern was duplicated by only two of six Ss tested with N, and two of six tested with D. The differences between the compound test stimulus and the more suppressed of the preceding single stimuli were significantly greater than the corresponding differences for either of the single-stimulus test groups [Whitney's extension of the Mann-Whitney U test, $Pr(h = 2.40)$, $Pr(h = 2.64) < .01$]. In extinction, 11 of 13 Ss showed greater suppression to the compound than to any of

the individual stimuli immediately preceding and following it.²

EXPERIMENT 2

In the second experiment, a compound consisting of CS+ and CS- from a differential conditioning situation was studied. Since the effects of a compound could be produced by some nonassociative factor such as "novelty," a compound consisting of a CS+, and a "neutral" stimulus (CS°) was also studied.

Subjects

The Ss were 24 male hooded rats, deprived and maintained as in Experiment 1. One S died before the experiment was completed, and the data from two others were discarded because of very low VI baselines.

Apparatus

The apparatus was that used in Experiment 1. The conditioned stimuli were darkness and 80-dB white noise. US intensity was that produced at the 1.3-mA setting of the shock generators. For each S, either D or N was selected as CS+. The other stimulus served as CS- for differential Ss and CS° for nondifferential Ss.

Procedure

The pretest CS presentations, food-reinforcement schedule, and the temporal parameters of classical conditioning were the same as in Experiment 1. Conditioning took place over 4 consecutive days. On each of the first 2 days, three shock-terminated CS+ presentations were scheduled. On the third

Fig. 1. Suppression ratios for single CSs and compound CSs in Experiment 1 (upper portion) and Experiment 2 (lower portion) are shown. In Experiment 1, the order of single-stimulus presentations was counterbalanced. The lines joining certain points indicate that the joined data points are from one group of Ss.

and fourth days, the differential training groups received three CS+ trials paired with shock, and three CS- presentations never paired with shock. Nondifferential Ss continued to receive only three reinforced CS+ trials on each of the last 2 days of training. No stimulus presentations were made during the session following the completion of training in order to allow bar-pressing baselines to recover.

Extinction began on the next session. For the differentially trained Ss, four extinction trials of CS+ were scheduled daily, until the .20 criterion was satisfied. On the next trial, a CS- was presented, followed by a test trial on which CS+ was presented for half the Ss and the CS+/CS- compound for the other half.

On the following day, CS+ was presented again. When the .20 criterion was met within four trials, a CS- trial followed, in turn succeeded by either CS+ or CS+/CS-, whichever had not been tested on the previous day. The same procedure served for the nondifferential group, with CS+ replacing CS-.

Results

Both groups of Ss showed almost complete suppression by the second day of acquisition. No significant suppression to the CS- occurred when it was introduced on Day 3 of acquisition. By Day 4, however, differential Ss exhibited significant acceleration to CS- (median Day 4 CS- ratio = .56, Wilcoxon $T = 2$, $n = 11$, $p < .01$), indicating that CS- had an effect on responding different from that of the background stimuli.

The results of both test blocks for the differential and nondifferential groups are shown in the lower section of Fig. 1. The three points on each curve represent the CS+ criterion trial, the subsequent CS- or CS° trial, and the tests of either CS+ or the appropriate compound. For all Ss in the differential group, the compound produced less suppression than the test CS+ (Wilcoxon $t = 6.5$, $n = 11$, $p < .05$); for Ss in the nondifferential group, there was no significant difference between compound and test CS+. Furthermore, the magnitude of the difference between test CS+ and compound was significantly greater for differential Ss than for nondifferential Ss (Mann-Whitney $U = 26.5$, $n = 21$, $p < .05$).

DISCUSSION

When the results of the two experiments are combined, they indicate that (1) two CS+s, when presented in compound, produce more suppression than either alone; (b) a CS+ and a CS-, when presented in compound, produce less suppression than the CS+ alone; and (c) a compound consisting of CS+ and a "neutral" CS° produces suppression which does not differ from CS+ alone. Furthermore, these results

were obtained after relatively little training, in contrast to other experiments which studied compounds of CS+s (Miller, 1969) and of a CS+ and CS- (Hammond, 1967) after extensive single-stimulus training.

These data indicate that the same results are obtained for compounds of classically conditioned stimuli as for compounds of operantly conditioned stimuli (Cornell & Strub, 1965). Furthermore, the inclusion of the CS+/CS° compound in the present experiment permits one to rule out certain interpretations of the data. The possibility that the effect of either compound stimulus could be accounted for by some "novelty" effect leading to increased suppression, or generalization decrement leading to decreased suppression, is not supported by the outcome of the second experiment. Novelty, or generalization decrement, should have led to a change in responding to the CS+/CS° compound as well as to the CS+/CS- compound. This did not occur. The simplest and most compelling explanation of the data is that the effect of a compound is produced by some combination of excitatory strengths tending to suppress bar pressing, and inhibitory strengths tending to attenuate the suppression. If this explanation is correct, the compound procedure will permit one to determine the excitatory or inhibitory properties of an unknown stimulus, as do the conditioned-inhibition (Pavlov, 1927; Brown & Jenkins, 1967) and the

generalization of inhibition (Jenkins, 1965) techniques. If it is excitatory, a compound of the unknown stimulus and a CS+ should produce more suppression than either stimulus alone; if it is inhibitory, the compound should produce less suppression than the CS+.

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NOTES

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2. Examination of VI baselines throughout the conditioning and extinction sessions revealed no systematic difference which could account for the test trial outcomes. This was also true of the second experiment.

Conditioned suppression on a fixed interval schedule of reinforcement¹

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part by the temporal relationship between the CS onset and the presentation of a reinforcement.

The key-pecking behavior of two pigeons was maintained on a 2-min fixed-interval schedule of reinforcement. The interval was divided into four 30-sec periods, and an Estes-Skinner conditioned-suppression procedure was superimposed on the second, third, and fourth 30-sec periods of the fixed interval. Suppression was obtained during the second 30-sec interval, but a complete loss of suppression was obtained when the CS was presented during the last 30-sec period prior to a reinforcement. The results serve to complete the generalization that the severity of conditioned suppression on fixed schedules of reinforcement is determined in

The present study was designed to measure changes in the severity of conditioned suppression as a function of the placement of the preshock stimulus within a fixed-interval schedule of reinforcement. The behavioral effect of conditioned suppression is defined as a decrease in the rate of a positively reinforced response during a stimulus (CS) which precedes shock (Estes & Skinner, 1941). The defining characteristic of the procedure is that the stimulus and shock are superimposed on the baseline independently of the baseline performance.