Differential eyelid conditioning: The generalization of reinforcement and of nonreinforcement*

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In two human differential eyelid studies, Ss were first differentially conditioned to two tonal CSs, after which a third CS (CS_3) was introduced in random sequence with the established CS+ and CS–. The quality of CS_3 was either a red light (Experiment I) or a tone (Experiment II). As a tone (Experiment II), CS_3 was either more similar to CS+ than CS–, or vice versa. In both studies, the percent of CS_3-UCS pairing varied factorially between groups as 0%, 20%, or 60% of the CS_3 trials. As was true in earlier studies, the historic notions of reinforcement and stimulus generalization were not adequate to explain the results.

The two experiments were designed to estimate the effects generalized from established CS+ and CS– by introducing a third CS, CS_3, into random sequence with CS+ and CS– after differential responding was obtained.

EXPERIMENT I

The first experiment was designed to demonstrate the effects of introducing a new association (CS_3-UCS) in addition to the associations already established in the initial differential conditioning phase. To eliminate differential generalization from either CS+ or CS– to CS_3, CS_3 differed in modality from CS+ and CS–. By varying the percent of CS_3-UCS pairings (between groups) the design allowed for an estimate of the effect of introcuding a new association, where the strength of CS_3-UCS association varied with percent CS_3-UCS pairing.

Method

Apparatus

An S sat facing the back wall of a 1.219 x 1.523 m enclosure, painted flat white, an 8-ohm speaker centered in the ceiling, and an IEE display cell encased in a 152 x 152 x 304 mm box at eye level on the back wall. The S was fitted with a Waltke headband, which supported an airjet (1.53-mm orifice) and a Gianninni Minitorque rotary potentiometer (Model 35153). The latter was connected by tape and light piano wire to the S's upper right eyelid. The resistance changes relayed from the potentiometer were amplified and recorded on an Offner Type R recorder.

All CSs had a 900-msec duration, and on reinforced trials a CS terminated with a 100-msec duration puff of nitrogen, providing an 800-msec CS-UCS interval. The UCS intensity was 125 mm Hg static pressure (2.45 psi). Four intertrial interval values of 9, 12, 15, and 18 sec (13.5 sec average) were randomized. The two tonal CSs were hertz values of 600 and 1,000 at 75 dB SPL, generated by Hewlett-Packard oscillators (Model 204D). The assignment of the 600- or the 1,000-Hz tones as CS+ and CS– was counterbalanced among Ss. The third CS (CS_3) was a red light emitted from a 28-V dc bulb in the IEE display cell. A Grason-Stadler (Model 901-B) noise generator, at 70 dB SPL intensity, masked extraneous sounds.

Procedure and Design

Following "neutral" instructions, each S received three blocks of 24 differential conditioning trials involving the random sequencing of 12 CS+ and 12 CS– trials per trial block. Following the initial differential conditioning phase, each S experienced two blocks of 60 trials with the three CSs presented in random sequence 20 times per block. Three groups of Ss were distinguished by the percent of total CS_3 trials, which were reinforced (paired) with the UCS, 0%, 20%, or 60%. The design involved two levels of counterbalancing (of the two hertz values of tones as CS+ and CS–) and three values of percent CS_3-UCS pairings. The three levels of percent CS_3-UCS were selected on the basis of previous work (Peterson & Newman, 1970).

The criterion of reliable differentiation during the first training phase was derived from a post hoc analysis of a separate pilot study. The 12 male pilot Ss received 96 differential conditioning trials. The pilot data showed that for 9 of the 12 Ss, if a difference score of 41.67% more CRs to CS+ was obtained on Trials 49-72, then a difference score of at least 25% was observed over Trials 73-96. For the actual experiment, each S was assigned randomly to one of the six groups and run accordingly. If the S's difference score on Trials 49-72 was at least 41.67%, he was then labeled as a "good" (i.e., reliable) differentiating S. When a particular cell of the 2 by 3 design had six "good" Ss, assignment of Ss to that cell was discontinued.

Subjects

Eighty-five male introductory psychology students were run.[1] Data for six Ss were discarded because of apparatus failure and experimental error. There were 81% of the Ss showing positive difference scores. By the criterion of the 41.67% difference score on Trials 49-72, however, 36/79 Ss were "good" differentiating Ss; 28/79 showed positive difference scores below the criterion 41.67% ("poor" differentiators). Using the overall observed ratios of good, poor, and nondifferentiating Ss to estimate the expected number of each kind of differentiator in each of the six partitions, no significant departures from the expected frequencies were found (all p values >.10).

Results and Discussion

The results of only the reliable ("good") differentiators were analyzed in full.[2] The means of poor and nondifferentiating Ss showed response patterns similar to the "good" differentiators; however, problems of empty and unbalanced cells and meeting distribution assumptions precluded analysis of the poor and nondifferentiating Ss' data. The two panels of Fig. 1 represent the percent CRs to each of the three CSs

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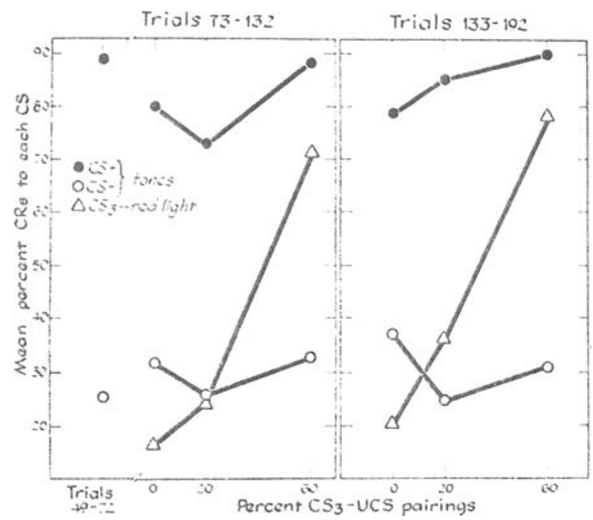

Fig. 1. The mean percent CRs to each CS for Experiment I are presented. The left-hand panel gives the percent CRs to CS+, CS–, and CS_3 by percent CS_3-UCS pairing average over Trials 73-132. The first point on the abscissa of the left-hand panel represents the last block of CS+ and CS– trials prior to the introduction of CS_3 (Trials 49-72). The right-hand panel provides the mean percent CRs to each CS for Trials 133-192.

during the last two blocks of 60 trials. The left panel also presents the percent CRs to CS+ (closed circle) and CS– (open circle) for the trial block preceding the introduction of CS_3 (Trials 49-72). The percent CRs to CS+ and CS– on Trials 49-72 provide reference points representing the levels of responding prior to introducing CS_3 trials.

As the percent CS_3-UCS pairings increased, there was a significant linear increase in percent CRs to CS_3, $F(1,30) = 40.45$, $p < .001$. The CS_3 results were anticipated and represent the typical partial reinforcement acquisition effects.

Using the percent CRs to CS+ on Trials 49-72 as a reference point, the percent CRs to CS+ were contrasted for each of three groups. When percent CS_3-UCS pairing was 0% or 20%, the percent CRs over CS+ trials showed a decrease on the first block of 60 trials after CS_3 introduction (Trials 73-132), $F(1,30) = 15.83$, $p < .01$. On the other hand, only the 0% group (and not the 20% group) retained the depressed level of percent CRs to CS+ on the last block of trials, $F(1,30) = 4.81$, $p < .05$. In summary, then, there was a significant and lasting decrease in response tendency to CS+ when percent CS_3-UCS pairing was zero, while only temporary decrease was observed when percent CS_3-UCS pairing was low (20%) and no depression of response tendency to CS+ was observed when percent CS_3-UCS was high (60%). Assuming that the percent CRs to CS+ in the 60% group were at a ceiling of responding, then the results would be expected on the basis of an overall increase in the number of reinforcements per 60-trial block.

Initially, CRs to CS– were not significantly affected by the introduction of CS_3 (all contrasts produced F ratios less than 1.75). By the last trial block (Trials 133-192), however, the 0% CS_3-UCS group showed a significant increase in percent CRs to CS–, $F(1,30) = 6.000$, $p < .05$.

Within Group

When percent CS_3-UCS pairs was zero, the percent CRs to CS– was greater than the percent CRs to CS_3 over both the last two trial blocks, $F = 5.004$, $p < .05$. The result was reasonable if one assumes that responding to a tonal CS– would be affected by the response tendency generalized from tonal CS+. No such generalization would be expected from tonal CS+ to CS_3 (a red light). It was not clear why the percent CRs over CS– trials increased for the 0% group and remained stationary for the 20% group after CS_3 was introduced instead of lowered as predicted by excitation-inhibition theory (Gynther, 1957). Peterson and Newman (1970) found responding to CS– to be remarkably stable over 240 differential conditioning trials.

When the percent of CS_3-UCS pairings was 20%, a different picture emerged. The percent CRs to CS– and CS_3 were approximately equal to each other and approximately at the level of responding shown to be true on CS– trials prior to introducing CS_3 (Trials 49-72). The percent CRs to CS+ dropped initially, as indicated above. On the last trial block, the percent CRs to CS+ returned to its earlier level and the percent CRs to CS_3 rose above the level of CRs to CS–. A sign test showed that significantly more Ss (9 of 11 Ss) had a greater number of CRs to CS_3 than to CS– ($p < .05$), but a t test did not show significance, $t(22) = 1.157$, $p > .05$. Thus, aside from the decisively strong linear trend across reinforcement schedule groups for percent CRs to CR_3, there was little evidence that Ss in the 20% group differentiated CS_3 and CS–.

For the 60% CS_3-UCS group, the percent CRs to CS+ and to CS– were the least affected by the introduction of CS_3. There was a tendency for the number of CRs to CS– on the last two trial blocks to be greater than the number of CRs to CS– during the earlier phase of training (Trials 49-72), but the results of neither the t nor the sign tests were significant.

EXPERIMENT II

Contrary to Experiment I, the physical character of CS_3 in Experiment II was either more similar to CS+ (site of excitation) or to CS– (the site of inhibition). The percent of CS_3 pairings was again varied, but here the purpose was to accentuate the extent of generalization from CS+ or CS– as a function of CS_3-UCS association.

Method

Apparatus, Procedure, and Design

All features were the same except that CS_3 was either a 700- or a 900-Hz tone. For the design, the additional two-level variable of CS similarity was crossed with percent CS_3-UCS pairings and the counterbalanced assignment of CS+ and CS− to the 600- and 1,000-Hz tones.

Subjects

The distinction of "good," "poor," and "nondifferentiating" Ss was also used in Experiment II. The design involved 12 groups in the final partitioning, and Ss were assigned randomly to each partition until five "good" differentiating male Ss were in each. There was a total of 184 male introductory psychology students run, with 16 Ss lost to E error or apparatus failure. Of the 169 remaining Ss, 79% showed positive difference scores: 60/169 were "good" and 73/169 "poor" differentiators. Again no significant departures from the expected frequencies were detected ($p > .10$), and only the results of "good" Ss were completely analyzed.

Results and Discussion

The results of the CS_3 similar to CS+ groups are summarized in the upper two panels of Fig. 2; the CS_3 to CS− group results are presented in the lower two panels.

The adjusted linear trend of CRs to CS_3 across levels of percent CS_3-UCS pairings, while significant, $F(1,48) = 46.57$, $p < .001$, appeared to be flatter in Experiment II. The CS similarity effect on the percent CRs to CS_3 manifest a significant difference in the adjusted quadratic trends, $F(1,48) = 9.52$, $p < .005$. The difference was apparently due to the smaller increase in the percent CRs to CS_3 from the 0% group to the 20% group under the CS_3 similar to CS+ condition.

The functions at both levels of CS similarity differed from that observed in Experiment I. When CS_3 was more similar to CS−, there were no statistically reliable effects on the percent CRs to CS+ for either the introduction of CS_3 trials or the schedule of percent CS_3-UCS pairings variable. On the other hand, some rather marked effects were observed when CS_3 was more similar to CS+ than to CS−. There was an overall decrease in percent CRs to CS+ after CS_3 trials were introduced $F(1,48) = 11.19$, $p < .01$. Moreover, a contrast of linear trends across percent CS_3-UCS pairings by trial block was significant, $F(1,48) = 7.14$, $p < .025$. The difference in linear trends was due to an increase in percent CRs to CS+ for the 0% and 20% groups, but not the 60% group, $F(1,48) = 13.29$, $p < .01$. Thus, the decrease in the percent CRs to CS+ for the 0% and 20% groups was only temporarily affected by CS_3 trials.

The introduction of the tonal CS_3 trials resulted in an overall increase in the percent CRs to CS−, $F(1,48) = 10.54$, $p < .005$. Two interesting effects were found (post hoc) to be influenced by CS similarity. First, when CS_3 was more similar to CS+, the increase in percent CRs to CS− was reliable for only the 60% group, $F(1,48) = 13.33$, $p < .05$. Second, for the CS_3 similar to CS− condition, the increase in percent CRs to CS− was significant for only the 0% and 20% groups, $F(1,48) = 7.21$, $p < .05$.

Together, these results suggest that generalization between the newly introduced CS_3 and either of the established CSs (CS+ or CS−) was greatest when the physical similarity between two CSs was high and when

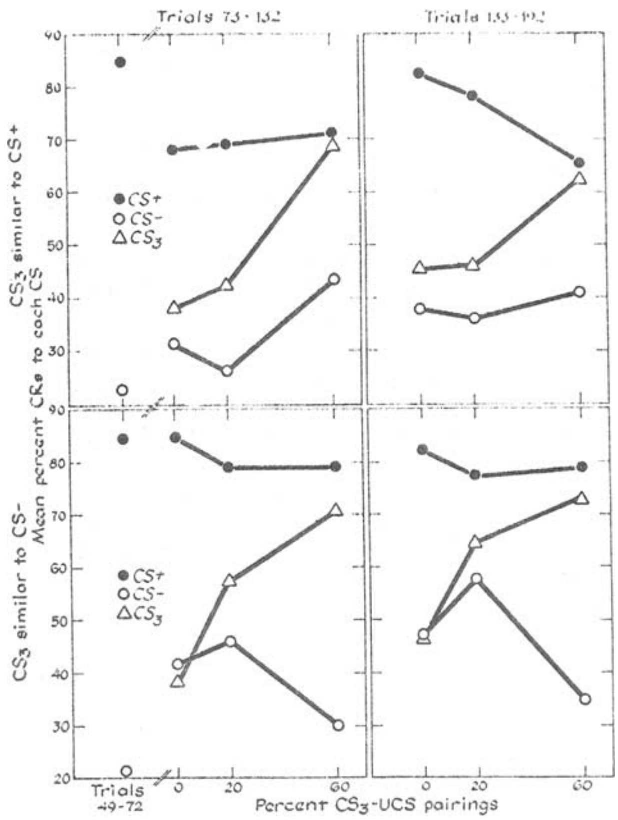

Fig. 2. The mean percent CRs to each CS for Experiment II are given. The effects of CS_3 more similar to CS+ condition are presented in the upper two panels. The lower two panels give the results of CS_3 more similar to CS− condition.

the schedule of CS_3-UCS pairings was most similar. The interplay between CS_3 and CS+ was greatest when CS_3 was more similar to CS+ than CS− and when the percent CS_3-UCS pairing was 60%. Likewise, the interplay between CS_3 and CS− was greatest when CS_3 was more similar to CS− than CS+ and when the percent CS_3-UCS pairings was either 0% or 20%.

The fact that the strongest generalization effects were observed between two Ss when both CS similarity and similarity of reinforcement schedules were high was anticipated. On the other hand, the nature of the effects was not predictable from excitation-inhibition theory. The inconsistencies with theory can best be seen by considering the two extreme cases of high stimulus and schedule similarity. Theory predicts that generalized effects of reinforcement would be greatest when CS_3 and CS+ were similar and the CS_3-UCS schedule was 60%. The surprising result was the marked decrease in the percent CRs on CS+ trials. The decrease in percent CRs to CS+ was such that there were no differences in percent CRs on CS+ and CS_3 trials. Moreover, the percent CRs on CS_3 trials was no higher in this group than in any other group. It is difficult to conceive that the 40% nonreinforced CS_3 trials in the 60% group were more effective in generalizing inhibitory effects than they were in the 0% or 20% groups. For the 0% and 20%

groups (CS_3 and CS+ similar), an initial decrease in percent CRs to CS+ was observed, but the decrease did not persist into the second block of 60 trials as was observed in the 60% group.

At the other extreme was the 0% group, for which CS_3 was more similar to CS– than CS+, and the inhibitory effects should have been optimal. The introduction of the nonreinforced CS_3 trials resulted in a reliable increase in the percent CRs to CS– equal to the level observed on CS_3 trials. Furthermore, the percent CRs on CS+ trials maintained at the pre-CS_3 level instead of decreasing. A decrease was anticipated because of the increased potential for generalized inhibition from both CS_3 and CS–. The same set of results was observed in the 20% group with CS_3 similar to CS–. Specifically the percent CRs to CS_3 and to CS– for the 20% group were relatively higher under the CS_3 similar to CS– condition than under the reversed CS similarity condition. Furthermore, the percent CRs on CS_3 trials were lower for the 60% group under the CS_3 similar to CS+ condition. As such, the results were opposed to an excitation-inhibition interpretation. Recently, Allan & Branum (1971) suggested that gradients of generalized excitation and inhibition would be flatter in situations involving partial reinforcement. Even the extension of excitation-inhibition theory proposed by Allan and Branum fails to justify the inconsistencies found here.

The present experimental results showed that excitation-inhibition theory did not provide a satisfactory explanation for a two-phase conditioning procedure. Since the formal analysis used the data of only those Ss who were clearly differentiating at the end of the first conditioning, one is tempted to postulate the additional effects of awareness (Perry, Grant, & Schwartz, 1971) or the information signaling properties of the various CSs (Grant, 1968). While the first training phase served to establish the differential conditioning process, the introduction of CS_3 in the second phase may have had differential cuing effects of the sort described by Grant (1972).

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NOTES

1. Female Ss did not volunteer in sufficient numbers to provide a proportionately balanced design.

2. All analyses were performed on the arcsin transforms of the percent CRs. All trend analyses involved coefficients adjusted for the unequal intervals across the percent CS_3-UCS pairing variable (0%, 20%, and 60%).

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