Differential conditioning along two dimensions and stimulus generalization of the rabbit's nictitating membrane response*

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Rabbits received classical differential conditioning of the nictitating membrane response to tones differing in both frequency and intensity. Subsequent tests of stimulus generalization along the frequency dimension (at the intensity of CS+) indicated significant suppression of responding to the CS− frequency compared with control groups conditioned to CS+ alone. These results are consistent with Hullian (gradient interaction) theories of discrimination learning.

The operant conditioning literature contains numerous demonstrations that intradimensional discrimination training produces, among other effects, a steeper generalization gradient (most notably on the S− side of the peak) than that obtained as a result of single-stimulus training to S+. Liu (1971) has reported similar results for the classically conditioned nictitating membrane (NM) response of the rabbit. In Liu's experiment, differential conditioning to tones of 1200 Hz (CS+), 2400 Hz (CS−), and equal intensity (75 dB SPL) resulted in a sharper relative generalization gradient along the frequency dimension than that obtained from a single-stimulus control group conditioned to the 1200-Hz tone. The greatest suppression of generalized responding occurred on the CS− side of the gradient, thereby conforming with the operant literature and with traditional Hullian theories of discrimination learning. However, Liu (1971) found that when CS+ and CS− differed in both frequency and intensity (CS+ was a 1200-Hz tone of 75 dB and CS− was a tone of 2400 Hz of 60 dB), the observed generalization gradient along the frequency dimension was indistinguishable from that of the single-stimulus control.

Two factors may have contributed to Liu's failure to observe any effect of differential conditioning on generalization in the two-dimensional case: (1) Conditioned inhibition from the less intense CS− may have been too weak to influence excitatory generalization; (2) the psychophysical distance between CS+ and CS− in the frequency by intensity space may have been so great that any inhibition at CS− could not generalize far enough to influence the excitatory gradient. The present investigation sought additional information on the excitatory auditory frequency generalization as a function of differential conditioning to tones differing in both frequency and intensity.

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METHOD

Subjects and Apparatus

Sixty-four New Zealand rabbits were run, four at a time, in individual soundproofed and ventilated file drawers while restrained in Plexiglas boxes like those described by Gormezano (1966). A potentiometer mounted on the S's head was connected by a small metal hook and thread to a nylon loop sutured into the nictitating membrane (NM) of the right eye. Movement of the NM resulted in a dc signal which was amplified and recorded on a Grass 5D oscillograph. A CR was defined as a pen deflection of 1 mm (corresponding to an extension of the NM of less than 1 mm) or greater within the 400-msec interstimulus interval. The CSs were 450-msec pure tones of 75 or 95 dB SPL, terminating together with the 50-msec UCS. The UCS was a 2-mA ac shock, delivered through wound clip electrodes (Clay-Adams, 9 mm) attached to the infraorbital region of the right eye. A low level (76 dB SPL) of continuous masking noise was provided by a speaker located directly in front of S.

Design and Procedure

Ss were divided into eight groups of eight animals each, according to a 2 by 2 by 2 factorial design: (a) One factor of the design was single-stimulus (simple) conditioning to one CS vs differential conditioning to two CSs; (b) another factor, orthogonal to (a), was the intensity of the reinforced CS (95 vs 75 dB). For the differential conditioned groups, CS− was 95 dB when CS+ was 75 dB and 75 dB when CS+ was 95 dB. (c) The third orthogonal factor was the frequency of the reinforced CS (900 vs 1500 Hz). For the differential conditioning groups, CS− was 900 Hz when CS+ was 1500 Hz and 1500 Hz when CS+ was 900 Hz. The day following suturing and adaptation to restraint, differential conditioning Ss received four successive daily sessions of 50 CS+ and 50 CS− trials (in an unsystematic order) at a constant ITI of 30 sec. Single-stimulus Ss received four daily sessions of 50 reinforced trials, at an ITI of 60 sec. Training was followed by two daily extinction-generalization test sessions, consisting of 15 presentations each of seven test tones (300, 600, 900, 1200, 1500, 1800, and 2100 Hz) *at the intensity of CS+.*

RESULTS AND DISCUSSION

Acquisition

Figure 1 depicts the percentage of CRs for simple (single-stimulus) and differential conditioning groups as a function of day of training. Analysis of variance of CR frequency to the reinforced CS, pooled over the 4 days of acquisition, indicated significantly more CRs to the 95-dB tone than to the 75-dB tone [$F(1,56) = 17.21$, $p < .001$].

An analysis of variance of CR frequency confined to the differential conditioning groups, with CS+ and CS− as a within-Ss factor, indicated a significant difference in responding to CS+ and CS− [$F(1,28) = 158.99$,

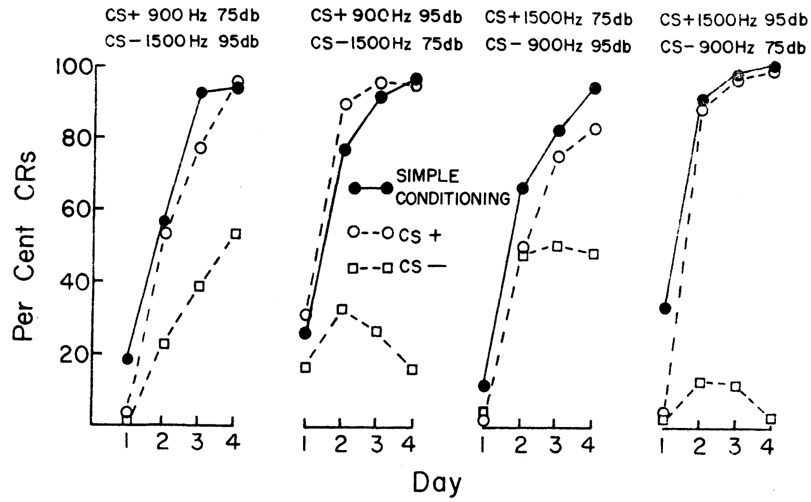

Fig. 1. Percentage of CRs as a function of day of training for Experiment I.

p < .001]. Analysis of variance also indicated that differentiation was greater for groups trained with a CS+ of 95 dB and CS− of 75 dB than vice versa [F(1,28) = 39.33, p < .001]. This difference was due to both a higher level of responding to CS+ and a considerably lower level of responding to CS− in the former case compared with the latter. This pattern of results is basically consistent with other rabbit (Schneiderman et al, 1971) and human conditioning studies (e.g., Moore, 1964).

Stimulus Generalization

The mean relative generalization gradients for each group, pooled over the two test sessions, are depicted in Fig. 2. In order to determine whether differential conditioning affected frequency generalization, the relative percentage of CRs to the CS− frequency of differential groups was contrasted with the relative percentage of CRs to the same frequency of simple conditioning controls. Figure 2 shows that this measure was consistently lower, on the average, for differential conditioning groups than for their respective controls, and an analysis of variance indicated a significant main effect of differential vs simple conditioning on relative responding to the CS− frequency [F(1,56) = 7.90, p < .01].

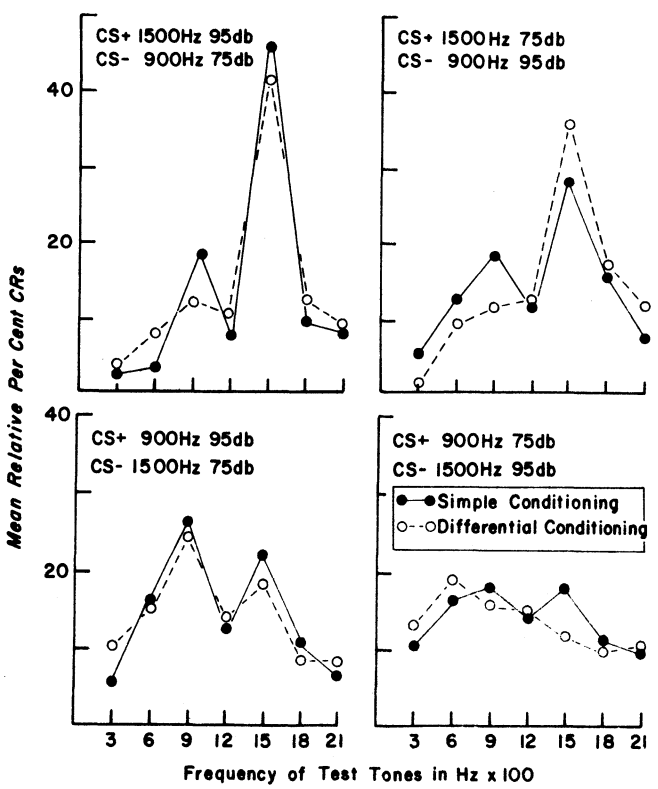

Fig. 2. Mean relative percentage of CRs to test tones, pooled over the two test sessions of Experiment I.

Figure 2 reveals a depression of generalized responding at the center test frequency (1200 Hz) in six out of eight gradients. This effect may have been due to generalized extinction inhibition from the other test stimuli. Such generalization effects would tend to be greatest at the center frequency. However, this curious depression at 1200 Hz was not statistically significant according to a variety of tests.

The principal finding of this experiment is that differential conditioning along two dimensions affected generalization in a manner consistent with traditional Hullian theory of discrimination learning. This theory states that the observed gradient represents the interaction of underlying excitatory and inhibitory gradients. In the present experiment, gradient interaction is reflected in the finding that the generalization gradients of differential conditioning groups were suppressed on the CS– side of the test dimension in comparison with controls. The absence of other effects of differential conditioning on generalization does not necessarily argue against gradient interaction. Dramatic distortions of the observed gradients of the differential conditioning groups, such as peak and area shifts (cf. Moore, 1972), were not anticipated because of the relatively large separation between CS+ and CS– in the two-dimensional frequency by intensity space. Peak shifts along the audio-frequency dimension probably necessitate the use of CSs which are psychophysically closer together.

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