The assessment of excitation and inhibition by air puff elicited startle¹

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Following differential conditioning, an attempt was made to measure excitation and inhibition by recording the startle response elicited by an air-puff probe during presentation of the CS. A CS that predicted shock during conditioning became an excitator as evidenced by greater startle magnitude in its presence relative to the startle magnitude of a random control group. A CS that predicted shock absence, however, did not become an inhibitor.

Rescorla (1967, 1969) has proposed a contingency conception of Pavlovian conditioning in which excitation and inhibition are regarded as symmetrical processes. The contingency is determined by the relative probability of the occurrence of the US in the presence of the CS (or its trace) vs the probability of the US in the absence of the CS. If the probability of the US is high in the presence of the CS and low in its absence, excitatory conditioning occurs. When US probability is low in the presence of the CS and high in its absence, inhibitory conditioning will result. Furthermore, whatever the behavioral consequences of the presentation of an excitatory CS, an inhibitory CS is assumed to have effects on behavior opposite to those of an excitatory CS.

In the present experiment, a technique similar to that devised by Brown, Kalish, & Farber (1951) was used to assess the excitatory or inhibitory properties of a CS. Thus, a startle stimulus was presented in the presence of a CS that had been previously either correlated or uncorrelated with the US. Presumably, a CS that is regularly followed by a US such as shock will produce excitation (conditioned fear), while, on the other hand, a CS that reliably predicts a period free of the US will produce inhibition. On the assumption that a CS that produces excitation or fear has drive properties, it follows within the framework of drive theory (Brown, 1961) that all stimulus-response tendencies should be enhanced by its presence. Indeed, Brown, Kalish, and Farber found that the magnitude of an unconditioned reaction (startle response) in the presence of a CS increased significantly relative to the preconditioning level following CS-shock pairings. According to Rescorla, an inhibitory CS should control a behavior tendency opposite to an excitatory CS.

Given both theoretical and empirical reasons for expecting an excitatory CS to augment the unconditioned startle response, an inhibitory CS should produce the opposite effect, i.e., a depression of startle-response magnitude.

The baseline against which conditioning effects were measured was provided by the startle-response magnitude of a random control group. Rescorla maintains that the random control group in which no contingency whatsoever exists between CS and US is the appropriate control for nonassociative changes that take place in conditioning experiments.

SUBJECTS

Sixteen female albino rats, weighing 225-260 g, served as Ss. These Ss had previously been used in an alley shock-escape study.

APPARATUS

The apparatus used to record the startle reaction was a stabilimeter device, the basic sensing element of which was a postage scale (Hanson, Model 1509, 5-lb capacity) upon which was attached a platform, 3 x 7½ in., made of 1/16-in. aluminum. A grid, constructed of 15 stainless-steel rods (3/32-in. diam) spaced at ½-in. intervals in plastic side rails, was secured to the platform. Surmounting the grid was a detachable confinement box (3¼ x 7¼ x 5-3/8 in. high, i.d.) constructed of 1/8-in. Plexiglas.

Startle movements caused vertical displacements of the box, its platform, and of an Astatic phonograph cartridge that was attached thereto. The steel needle appropriate to that cartridge was replaced by a 1-in. rod having a 1.5-g weight at the end. This more massive "needle" tended, because of its inertia, to lag behind both upward and downward movements of the cartridge and, thus, to generate a voltage at the cartridge terminals. This signal was transmitted through a shielded cable to one channel of a Grass Model 5C polygraph, where it was amplified by an EEG preamplifier (Model 5E) and recorded by the oscillograph pen at a paper speed of 25 mm/sec. A second channel was used as an event marker to record presentations of startle stimuli. The startle response was measured as a maximum peak-to-peak pen deflection occurring within 0.4 sec of the startle-stimulus presentation.

The startle stimulus, a 55- to 60-msec air puff, was presented to the rat through 1-in.-diam holes in both ends of the narrow confinement box so the rat would be puffed in the face regardless of his

orientation. The air was delivered through a pair of 3/16-in. brass nozzles, the ends of which were approximately ½ in. from the holes in the ends of the box, which were centered about 2¼ in. above the grids. The static pressure in the puff-delivery system was capable of supporting a 115-mm column of mercury with one nozzle open.

Two tonal CSs were delivered through a 5-in. speaker located 8 in. diagonally below the confinement box containing S, and each raised the sound level about 2 dB (ambient level, 60 dB) on the C scale of a General Radio Co. sound-level meter (Model 1551-C). A 2,000-Hz tone was produced by a Heathkit audio oscillator (Model AG-10), while a 10,000-Hz tone was produced by a Hewlett-Packard wide-range oscillator (Model 200 CD). The US was a 0.5-sec, 1.0-mA scrambled shock produced by a Grason-Stadler Model E1064GS shock generator. The presentations of the startle stimulus, CSs, and US were controlled automatically by electromechanical programming equipment located outside the Industrial Acoustics Co. soundproof room that housed the stabilimeter.

PROCEDURE

The Ss were assigned randomly, eight per group, to either the differential-conditioning (DC) or the random-control (RC) group. Following 5 min of habituation to the apparatus, each S received two pretest trials with each CS on Day 1 only. At the end of each session, one test trial with each CS was administered. On both pretest and test trials, the air puff was presented 5 sec after CS onset. Test trials were spaced at intertrial intervals comparable to those of conditioning trials. Order of CS presentation was counterbalanced both within and between Ss.

For the DC group, CS1 was always followed by the 0.5-sec shock 5 sec after CS onset, the two events coterminating. CS2 was the same duration (5.5 sec) as CS1 but was followed only by the intertrial interval, which averaged 90 sec (60-120 sec, range). Twenty-five trials of each type were delivered on each of 4 successive days. On each day, a CS1 trial was given first, then a CS2 trial, until three trials of each type had been administered. After that, the CS1 and CS2 trials were randomly alternated for the remainder of the daily session. For half the Ss, CS1 was the 2,000-Hz tone and CS2 was the 10,000-Hz tone. The tones were reversed for the other half of the Ss.

For the RC group, CS1, CS2, and the US were all independently randomized on separate channels of a three-channel VI tape. The events were programmed in such a way that the probability of an event onset was a constant throughout the

Fig. 1. Mean startle response in millimeters for the DC and RC groups for CS1 and CS2 pretest and test trials.

demonstrated that fear can be conditioned to apparatus cues as well as to a discrete CS.

An additional question that might be raised with respect to the failure to find inhibition concerns the use of the startle-response measure. Specifically, one might argue that the air-puff-elicited startle response cannot be pushed below the random control level. It should be clear from Fig. 1, however, that startle magnitude of Group RC is not at a physical floor. Obviously, startle responses of less than the mean value (20 mm) were obtained. Indeed, startle responses as small as 6 mm were recorded. For this reason, it does not seem reasonable to argue that the CS2 startle responses of Group DC could not be decremented below the random control level.

conditioning session (see Catania & Reynolds, 1968, Appendix II). Each of the three events, CS1, CS2, and US, were independently programmed to occur 25 times during the session. Furthermore, a different VI tape was employed for each day of conditioning.

RESULTS AND DISCUSSION

Neither group showed differential responding in the presence of CS1 and CS2 on pretest trials. Furthermore, the difference between Group DC and Group RC was not significant.

Figure 1 shows the mean startle-response curves for both CS1 and CS2 for the DC and RC groups. For Group DC, the effect of CS1 vs CS2 was significant ($F = 23.82$, $df = 1/7$, $p < .05$). The effect of days and of the Days by CS interaction were not reliable. A similar analysis on the data for Group RC revealed that neither the main effects nor their interaction was significant. It should be noted, however, that for Group RC, CS1 vs CS2 is, in reality, a dummy variable. Both CSs represent independently randomized tones, and whether one is labeled CS1 or CS2 is purely arbitrary. For all remaining analyses, the CS1 and CS2 responses of Group RC are combined to form a common baseline.

To determine if excitatory conditioning had occurred, a comparison was made between the CS1 responses of Group DC

and the baseline provided by Group RC. The CS1 vs RC effect was reliable ($F = 15.99$, $df = 1/14$, $p < .05$) but not the effect of days or the Days by CS interaction. Thus, the magnitude of Group DC's startle responses in the presence of CS1 was significantly greater than the startle responses of the random control group.

If inhibitory conditioning had also occurred, Group DC's startle responses in the presence of CS2 should have been less than those of Group RC. Analysis of variance revealed, however, that CS2 responses did not differ from the RC baseline ($F < 1$).

Thus, in the present experiment, excitatory conditioning is clearly evidenced but not inhibitory conditioning. The failure to demonstrate inhibition is at variance with other recent findings (e.g., Rescorla & LoLordo, 1965), which clearly show inhibition as well as excitation following differential conditioning.

One might question whether or not there was an excitatory baseline against which to assess inhibition in the present experiment. Obviously, inhibition cannot be demonstrated unless there is something to inhibit. Shock presentations in the experimental environment, however, might reasonably be expected to have produced a baseline of fear conditioned to apparatus cues. McAllister & McAllister (1962) have

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NOTES

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