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Single-alternation patterning in a conditioned suppression procedure with and without trace stimulus support

JOHN J. B. AYRES
University of Massachusetts, Amherst, Massachusetts 01003

and

CHARLES N. UHL
University of Utah, Salt Lake City, Utah 84112

Rats in a conditioned suppression situation received an electric grid shock unconditioned stimulus (US) after every other conditioned stimulus (CS) for a total of 300 trials. These rats failed to show any evidence of single-alternation patterning. Thus, they did not suppress more to CSs paired with shock (R trials) than to CSs that were unpaired (N trials). Even when only R trials or only N trials were preceded by a salient predictive cue, only half the rats tested suppressed more on R trials than on N trials. These differences in responding were not large and developed late in training. It appears, therefore, that the stimulus traces of R and N trials do not exert much control in a "typical" conditioned suppression situation.

When the goalbox of a straight runway is baited on alternate trials, rats learn to run fast on baited, or "R," trials and slow on unbaited, or "N," trials. This differential behavior on alternating trials is termed "single-alternation patterning." Capaldi (1966, 1967) has offered a theoretical account of such behavior. His analysis assumes that a stimulus consequence of reinforcement from an R trial serves as an S^D for running on the following N trial; that is, on N trials, a stimulus consequence of the preceding R trial sets the occasion upon which running, if emitted, will not be reinforced. Likewise, the analysis assumes that a stimulus consequence of nonreinforcement from an N trial serves as an S^D for running on the following R trial; that is, on R trials, the presence of some stimulus consequence from the preceding N trial sets the occasion upon which running, if emitted, will be reinforced.

A number of workers have asked whether single-alternation patterning can be obtained in Pavlovian defensive conditioning preparations. Using the nictitating membrane response in the rabbit and a shock to the eye region as the US, Leonard and Theios (1967) failed to find evidence for patterning in 1,000 trials. Likewise, Hoehler and Leonard (1973) also failed to find patterning in that preparation, except under conditions expected to provide extra sources of stimulus control for the behavior.

We sought here to demonstrate single-alternation patterning in a different kind of animal defensive preparation than has been used heretofore. Specifically, we used the conditioned suppression procedure because it seemed to offer some potential advantages over the nictitating membrane preparation. First, even with only moderate shock-US intensities, suppression is usually asymptotically conditioned within 10 trials (e.g., Annau & Kamin, 1961). Second, discriminations between stimuli explicitly paired and stimuli unpaired with shock (e.g., Ayres, 1966) also occur rapidly. Thus, relatively few trials should be required to show convincingly either the presence or the absence of a discrimination such as single-alternation patterning. Third, the suppression procedure has been thoroughly worked out with the rat, which has been the species used in most of the patterning work in the runway.

Besides studying a "standard alternation patterning condition," that is, one in which reinforced (R) and nonreinforced (N) CS trials strictly alternated, we also examined two other conditions. Here R and N CS trials again strictly alternated, but a salient, directly observable pretrial stimulus preceded and terminated just before all N-trial CSs for some animals and just before all R-trial CSs for others. The first of these conditions is similar to the trace conditioned inhibition procedure studied by Frolov (see Pavlov, 1960, pp. 69-71); the second is the symmetrical opposite of that procedure. In both conditions, the pretrial stimulus is discriminative of either nonreinforcement or reinforcement and can there-

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fore be considered a supplement to the stimulus aftereffects of the preceding R or N trial, respectively. In most studies of single-alternation patterning, experimenters have taken great pains to ensure that such external stimuli were not present to contribute to patterning. In contrast, we deliberately provided them, reasoning that if patterning should fail to occur under standard alternation conditions, it would be useful to know if it could occur when highly salient and directly observable pretrial stimuli were present as predictive cues. It might be noted that similar pretrial stimulus procedures have recently been studied in the conditioned suppression situation by Reberg (1978). Reberg described his procedures as "sequential feature-negative" and "sequential feature-positive" discrimination procedures. The chief difference between our procedures and his is that our positive and negative "features" (i.e., our pretrial stimuli) were supplemented by the putative stimulus traces of preceding N and R trials, respectively. Since Reberg randomized the order of N and R trials, his "features" were not supplemented by such traces.

METHOD

Subjects

Nine male Long-Evans hooded rats from Charles River Company, Wilmington, Massachusetts were maintained in a continuously lighted room at approximately 80% of their free-feeding body weights, which ranged from 308 to 346 g.

Apparatus

Three Foringer Skinner boxes (26.2 x 25 x 30 cm) were housed in ventilated single-drawer metal filing cabinets, 2.5 cm thick. The roof of each box was the top of the cabinet. In each roof was an 11.5-cm-diameter observation hole with double-paned plastic windows covered with a hinged metal door. The floor of each box was composed of 12 stainless steel rods, 6 mm in diameter, spaced 2 cm apart center to center. On the left of the front panel, 8.8 cm above the grid floor, was mounted a lever made from a telegraph key. A static weight of 12-17 g on the lever was sufficient to close the switch and be recorded as a response. A Scientific Prototype food tray was mounted 6.2 cm above the floor near the center of the front panel. Two 28-V bulbs, encased in translucent cream-colored plastic caps, were mounted on the front panel 16.2 cm apart center to center and 16.2 cm above the floor.

Scrambled grid shocks, .5 sec long and of .5- or .8-mA intensity, served as USs. They were provided by three Grason-Stadler shockers (Model E1064GS). White noise served as both the N- and R-trial CSs. It was presented by a Grason-Stadler 901B noise generator via the speaker in the rear of each chamber; it raised the ambient noise level from 70 to 83 dB re 20 microN/m^2. For some rats, a pretrial (pre-CS) stimulus was also presented; it consisted of the termination of the normally on cue lights on the front panel and resulted in total darkness in the box.

Procedure

Preliminary training, designed to shape and stabilize barpressing, concluded with two 2-h sessions in which barpressing was reinforced on a VI 2-min schedule. This session length and schedule of reinforcement remained in use thenceforth.

Habituation training. In three sessions following preliminary training, the stimuli later to be correlated with shock were presented independently of responding to habituate or eliminate their unconditioned effects on barpressing. For the group that was to receive the "standard alternation" procedure during conditioning, 12 2-min bursts of white noise occurred in each session. Intertrial intervals, randomly selected by computer, ranged from 395 to 805 sec. Two other groups received these same noise bursts, but preceded by a directly observable pretrial stimulus. For both groups, the pretrial stimulus was a 2-min termination of the cue lights, ending 5 sec before noise onset. For one group, termed the "trace-odd group," this pretrial stimulus preceded all the odd noise trials. For the other group, termed the "trace-even group," the pretrial stimulus preceded all the even noise trials. Three rats were assigned to each group.

Conditioning. Conditioning was identical to habituation, except that all even-numbered noise trials terminated in the onset of a .5-sec scrambled grid shock. Thus, for the trace-even group, the pretrial stimulus predicted that the immediately following noise CS would be reinforced, and hence, it supplemented the stimulus aftereffects of nonreinforcement from the preceding N trial. For the trace-odd group, the pretrial stimulus predicted that the immediately following noise CS would not be reinforced, and hence, it supplemented the stimulus aftereffects of reinforcement from the preceding R trial.

Conditioning proceeded for 25 sessions (300 trials). During the first four sessions, the shock-US intensity was set at .5 mA to avoid depressing the baseline barpress rate initially with too high a shock intensity. For the remaining sessions, a shock intensity of .8 mA was used.

To check the possibility of unauthorized shock avoidance, we directly observed each rat during one R and one N trial in nearly every session. Pre-CS and post-CS behavior was also frequently observed.

Treatment of data. For each noise trial, an Annau-Kamin (1961) suppression ratio was computed. The ratio is D/(B + D), where D denotes the number of responses during CS and B, the number in a comparable period before it. A ratio of 0 indicates complete suppression to the CS; one of .5 indicates no effect. For the standard alternation group, the B period was the 2-min interval immediately preceding each noise CS. For the pretrial stimulus conditions, the B period was a 2-min interval beginning 245 sec before each noise CS. This B period was also used to compute a suppression ratio for the pretrial stimulus itself in which the latter's 2-min duration comprised the D period.

RESULTS AND DISCUSSION

No instance of unauthorized shock avoidance was seen at any time.

Mean suppression on odd (nonreinforced) and even (reinforced) trials is shown for each rat on each day of the experiment in Figure 1. The left panels show the results for the standard alternation condition; the middle and right panels show the results for the trace-odd and trace-even conditions, respectively. As is seen clearly in the left panel, no rat in the standard alternation condition showed any evidence of patterning. The solid and dotted curves representing suppression on even (reinforced) and odd (nonreinforced) trials, respectively, are totally intertwined. In the trace-odd condition, two rats, R15 and R16, appeared to learn the appropriate discrimination, but with some difficulty: R15 suppressed more to even-numbered (reinforced) noise trials than to odd-numbered (nonreinforced) trials in 12 of the last 13 sessions, as did R16 in 20 of the last 21 sessions. In the trace-even condition, R19 showed some evidence for reversed patterning. This rat suppressed more on the nonreinforced, odd trials than on the reinforced, even

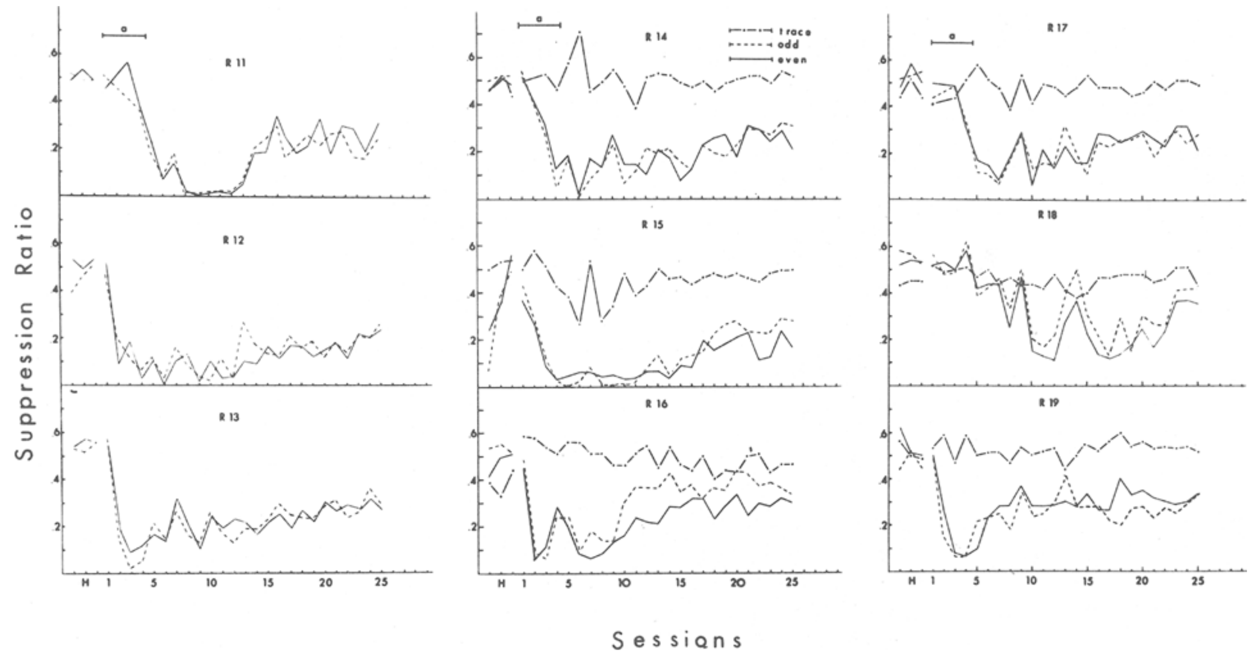

Figure 1. Daily mean suppression on odd, even, and "trace" (pretrial) CSs for each rat during 3 days of habituation (H) training and 25 days of conditioning. Left panels: standard alternation condition; even trials reinforced. Middle panels: trace-odd condition; odd (nonreinforced) trials preceded by pretrial CS. Right panels: trace-even condition; even (reinforced) trials preceded by pretrial CS. Shock intensity was .5 mA for first four conditioning sessions (marked "a") and was .8 mA thereafter.

trials in 11 of the last 12 sessions (for interpretation, see Prokasy, Carlton, & Higgins, 1967). Only R18 in the trace-even condition evidenced appropriately patterned behavior by suppressing more on even than on odd trials in 18 of the last 19 sessions. Suppression to both odd and even trials developed late in training for this rat and was cyclic thereafter. Extensive direct observation of this animal's barpressing and reaction to shock, however, revealed nothing unusual that might account for the peculiar record of suppression.

In general, the results from our trace-odd and trace-even conditions are similar to those obtained by Reberg (1978) in his sequential feature-negative and sequential feature-positive procedures, respectively. In both studies, the discriminative control exerted by pretrial stimuli was weak. Reberg found no control at all in his sequential feature-negative procedure and only very weak control in his sequential feature-positive procedure. We seem to have found somewhat more evidence for an appropriate discrimination in our trace-odd condition than Reberg did in his (formally similar) sequential feature-negative conditions, but whether this difference is due to parametric differences or to the extra support provided by the stimulus traces of preceding N and R trials in our study cannot be determined.

In addition to the discrimination between odd and even trials seen in some of the rats, two other discriminations are apparent in Figure 1. First, suppression weakened for all rats across the last 15-20 sessions. Such weakening is presumably due in part to the development of inhibition of delay, the discimination that initial portions of the CS are not reinforced (cf. Zielinski, 1966). Cumulative records (not presented) support this contention in showing that, late in training, suppression became confined to terminal portions of the noise-CS trials. Second, all rats in the pretrial stimulus conditions clearly showed an interdimensional discrimination (differential conditioning) by suppressing much more to the noise, which sometimes terminated in shock, than to the (darkness) pretrial stimulus ("trace" curve in Figure 1), which never terminated in shock.

It seems possible to rank order the kinds of discriminations seen in this study in terms of their magnitude and the speed with which they were established. From strongest to weakest, they appear to be (1) interdimensional differential conditioning, (2) inhibition of delay, and (3) discriminations based on directly observable pretrial stimuli. These discriminations provide a frame of reference against which to evaluate the absence of a discrimination based on the stimulus aftereffects of preceding trials (single-alternation patterning).

Table 1 presents a within-session analysis of terminal performance using data from the last three sessions (see footnote to Table 1). The entries are difference scores between adjacent pairs of trials. Positive scores indicate that suppression was greater on the even (reinforced) member of the pair than on the odd (nonreinforced) member; that is, they indicate patterning in the expected direction. In general, the within-session analysis supports the more molar analysis of Figure 1. For example, no rat in the standard alternation condition patterned appropriately within sessions, just as the between-session analysis

Table 1
Odd Minus Even Suppression Ratios on Adjacent Pairs of Trials

	Standard Alternation			Trace–Odd			Trace–Even		
Trial Pair	R11	R12	R13	R14	R15	R16	R17	R18	R19
1 – 2	–.10	+.01	+.15	+.16	+.13	+.22(+.20)	+.09	+.13	+.10
3 – 4	–.07	+.02	+.11	–.02	+.06	+.04(+.09)	–.06	–.02	–.20
5 – 6	–.04	–.03	–.09	+.05	+.07	–.02(+.08)	–.04	+.06	–.02
7 – 8	–.04	+.07	–.01	+.05	+.05	+.06(+.12)	–.06	+.09	+.07
9 – 10	–.04	–.03	–.01	.00	+.01	–.01(+.19)	–.02	+.07	–.15
11 – 12	–.14	+.02	–.04	+.06	+.21	+.04(+.16)	+.07	–.03	+.04
Mean Last Five Pairs	–.07	+.01	–.01	+.03	+.08	+.02(+.13)	–.02	+.03	–.05

Note–The scores are differences between ratios averaged over the last three sessions, except those in parentheses for R16, which are differences between ratios averaged over Sessions 12-14.

of Figure 1 suggests. Similarly, R15, which in Figure 1 appeared to pattern appropriately across sessions toward the end of training, also patterned appropriately within sessions on every pair of trials. The same was true for R16 during Sessions 12-14 (scores in parentheses). However, during the last three sessions, this rat's discrimination, which appeared to be maintained in Figure 1, was primarily due to differences in suppression on Trials 1 and 2. Differences between Trials 1 and 2 also contributed heavily to the discrimination shown in Figure 1 for R18 as well (see Table 1). In fact, eight of nine rats suppressed more on Trial 2 than on Trial 1, and for seven of the nine (R13-19), this difference was larger than the mean difference obtained on the remaining pairs of trials (compare the top row of Table 1 with the bottom row). The reason the difference scores were larger for the first pair of trials than for the remaining pairs was that there was virtually no suppression on the first trial. For example, in the last three sessions, the mean suppression ratio on Trial 1 was .46 (averaging across all nine rats). The corresponding means for the other nonreinforced trials (Trials 3, 5, 7, 9, and 11, respectively) were .27, .27, .27, .23, and .27. Every rat suppressed less on Trial 1 than on the mean of its remaining nonreinforced trials. This relatively weak suppression on Trial 1 stands in contrast to data (Ayres, Berger-Gross, Kohler, Mahoney, & Stone, 1979) obtained when all trials of a session are reinforced. Under these conditions, suppression on the first trial is at least as strong as that on other trials. It appears, therefore, that the relatively weak suppression seen in the present study on Trial 1 does not reflect some sort of warm-up effect but, instead, reflects a genuine pattern discrimination, that is, learning that the first trial is never reinforced. Like single-alternation patterning (when it occurs), this kind of pattern learning also, presumably, depends on the control exerted by pretrial stimuli. In this case, the stimulus traces that arise from an overnight stay in the home cage and from being handled and placed in the Skinner box are relatively unique to Trial 1. Like the (darkness) pretrial stimuli in the trace-odd condition of the present study, these stimuli should come to function as trace-conditioned inhibitors of suppression.

Although we have just seen evidence for a form of pattern learning on Trial 1, the main finding of this study is that in a fairly typical conditioned suppression preparation, single-alternation patterning does not occur unless the stimulus traces of preceding N or R trials are supplemented by other salient stimuli. Even then (in the trace-odd and trace-even conditions), discriminations aided by these supplemental cues developed late in training, occurred in only half the rats, and yielded only small differences in responding.

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