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The informational properties of S1, S2, and the S1-S2 sequence on conditioned suppression

KARL A. SEGER and CYNTHIA SCHEUER
Florida Atlantic University, Boca Raton, Florida 33431

The Egger-Miller information hypothesis was tested in a nonoverlapping compound stimulus CER situation. During CER training, S2, the so-called redundant stimulus, acquired greater suppression qualities than S1. However, following CER training, subjects were exposed to test situations in which the independent suppression qualities of S1 and S2 were assessed. S1 was followed by a trace interval, S2 was presented alone, or the S1-S2 sequence was reversed. Results of all test conditions showed minimal suppression to S2, while suppression to S1 was maintained or facilitated. It was suggested that S2, although a redundant predictor of shock occurrence, provides information as to "when" shock is due.

The present study attempted to extend the Egger-Miller information hypothesis (Egger & Miller, 1962) to a classical aversive situation as well as resolve some of the inconsistent results obtained in previous studies which employed aversive stimulation.

According to the information hypothesis, if two or more successive stimuli precede primary reinforcement, the first stimulus to occur, provided it is reliable, should become the more effective conditioned reinforcer. Normally, the second stimulus, because it is a redundant predictor of reinforcement, should not acquire conditioned reinforcing properties. The hypothesis was derived from studies investigating conditioned *positive* reinforcers in instrumental appetitive situations (Egger & Miller, 1962; 1963), and supported by McCausland, Menser, Dempsey, and Birkimer (1967).

The results obtained in aversive situations, however, have failed to show consistent support for the hypothesis. In a punishment situation, Seligman (1966) obtained support for the "weak" form of the hypothesis, showing greater suppression of the punished operant during the first stimulus than during the second stimulus. The second stimulus, however, did suppress behavior more than an event not explicitly paired with shock. Seligman suggested that the punishing power of the second stimulus resulted from its temporal contiguity with shock rather than its informational properties. Ayers (1967), using a conditioned suppression paradigm, demonstrated that redundant stimuli produced as much suppression as their more informative counterparts. Scheuer and Keeter (1969) confirmed Ayers' results using nonoverlapping rather than the overlapping compounds as Ayers had used. However, both Ayers and Scheuer and Keeter utilized the ongoing suppression ratios as indices of the conditioned reinforcing properties of each stimulus within the compound. Thus, the suppression obtained during the second stimulus could have been a result of a number of factors other than its informational qualities. The S2 suppression may have resulted from (1) its temporal contiguity to shock as Seligman suggests, (2) the informational properties of S1 termination independently of S2 presentation, or (3) the informational qualities of the S1-S2 sequence, i.e., the animals could have been utilizing the sequence rather than the individual stimulus elements as a cue for shock onset. In addition, as Scheuer and Keeter suggest, S1 could have served as a safety cue, signaling the start of a shock-free period, while S2 (or the offset of S1) served as a cue for "shock-about-to-come."

By incorporating some methodological refinements, the present experiment was designed to clarify the informational properties of S1 (onset and termination), S2, and the S1-S2 sequence in a nonoverlapping compound stimulus CER situation.

METHOD

Subjects

The subjects were 36 experimentally naive male albino rats purchased from the Holtzman Company, Madison, Wisconsin. The animals were 75 to 100 days old at the start of conditioning. The animals had free access to food during the experiment. Water was provided as reinforcement during conditioning and testing sessions, and for 10 min following each 1-h session. Of the 36 subjects, 6 were eliminated due to equipment failure or failure of the subject to meet specific criteria during initial conditioning.

Apparatus

Two modified operant conditioning chambers measuring 25 × 25 × 20 cm were housed in sound- and light-resistant containers in separate rooms. The floor of the chambers consisted of 18 metal grid bars. Three sides and the top were constructed of clear Plexiglas, while one side was dark Plexiglas

Reprints may be obtained from Dr. Cynthia Scheuer, Department of Psychology, Florida Atlantic University, Boca Raton, Florida 33431.

with a lever 7.5 cm above the grids. A 7.5 Vdc light with an orange shield was situated 5 cm above the bar, and a water dispenser was located 2.5 cm to the left of the bar. A Grason-Stadler Model 901B white-noise generator maintained a white-noise level of approximately 80 dB, as measured by a General Radio sound level meter, Type 1551C. The normal condition of the chambers was *white noise* and *light on*. Tape programmers, counters, and relay circuitry were in a separate room. A scrambled shock of 1.3 mA and 1 sec duration was presented through the grids using a separate Grason-Stadler Model 700 shocker for each chamber.

Procedure

The subjects were maintained for 3 days on 24-h water deprivation, receiving water for 10 min each day in their home cages. They were then shaped to barpress for water. During shaping, the chamber conditions were randomly varied, light on, light off, white noise on, white noise off, in order to habituate the subjects to the various stimulus conditions. All shaping, conditioning, and test sessions were 60 min long.

Gradually, the response requirement was raised to a VI 60-sec schedule. When response rates had stabilized on the VI 60-sec schedule, the subjects were given habituation trials to each stimulus (light off and noise off) in the absence of shock until a suppression ratio greater than or equal to .50 was maintained for three consecutive experimental sessions. Suppression ratios were computed for each component of the compound in the form CS/PRE-CS plus CS (Annau & Kamin, 1961). The ratio has limits of .00 and 1.00, with .00 representing complete suppression, .50 representing no effect of the CS, and 1.00 representing the case in which no responses occur prior to CS onset but some do occur during the CS.

Following habituation, CER training was initiated. CER training consisted of six daily presentations of a 30-sec period of S1, followed by 30 sec of S2. The termination of S2 was contiguous with the presentation of unavoidable shock. The offset of S1 was contiguous with the onset of S2, and intertrial intervals were varied.

For half of the animals (N = 15), S1 was the *offset* of white noise while S2 consisted of the *offset* of the cue light. These animals will be referred to as Group 1. For the remaining animals (N = 15), the stimuli were counterbalanced. S1 was light offset and S2 was noise offset. These animals will be referred to as Group 2.

The CER conditioning was continued until suppression ratios of less than .10 were obtained during each element of the compound for three consecutive sessions. On the day following attainment of criterion suppression, each subject was tested in two of three situations. The subjects were assigned to the test situations in a rotating order (i.e., Test 1-Test 2, Test 2-Test 3, Test 3-Test 1). Test trials replaced the second and sixth CER trial, and no shock was presented during test trials. Test 1 consisted of 30 sec of S1 followed by a 30-sec "trace" interval. Suppression ratios were calculated for S1 as well as the trace period. This test was incorporated to disentangle the informational (or suppressive) qualities of S1 termination independently of S2 occurrence.

Test 2 consisted of a 30-sec presentation of S2 alone. This condition enabled the measurement of S2 suppression independently of S1 occurrence. Test 3 consisted of 30 sec of S2 followed by 30 sec of S1 in order to determine any facilitative effect of the occurrence of S2 on subsequent suppression to S1.

RESULTS

Training

A comparison between the total number of responses to each stimulus (noise or light offset) revealed no significant differences [$t(29) = 1.46$; $p > .05$] during the first habituation trial.

The effect of the specific stimuli used in each element of the compound was tested by a comparison of the mean suppression ratios obtained during the last CER 5 days for Group 1 vs Group 2. No significant difference was obtained between groups for S1[$t(14) = 1.9$; $p > .05$] or for S2[$t(14) = .12$; $p > .05$]. This finding indicates that the specific stimulus used in each component of the compound was not a critical factor contributing to the extent of conditioned suppression.

A comparison of the suppression ratios obtained during S1 vs S2 on the final CER day revealed significantly greater suppression to S2 (Wilcoxon signed-ranks test; $p < .025$). As can be seen in Figure 1, suppression was essentially complete during S2 at the end of training, while S1 ratios stabilized at about .05.

From these data, it appears that S2 was the more effective conditioned reinforcer maintaining greater suppression of barpressing than S1, its more "informative" counterpart.

Testing

Table 1 gives the mean suppression ratios which occurred during each of the test conditions. Two-tailed tests of significance between the test ratios and those ratios obtained during the final CER training day were conducted for all conditions.

The results of Test 1 indicated little suppression during the trace period. As can be seen in Table 1, the mean ratio equaled .444, demonstrating that S1 termination was not responsible for suppression to S2 during training. If S1 offset had been a critical factor, we would have expected at least as much suppression during the trace period as occurred during S2 during the final day of training.

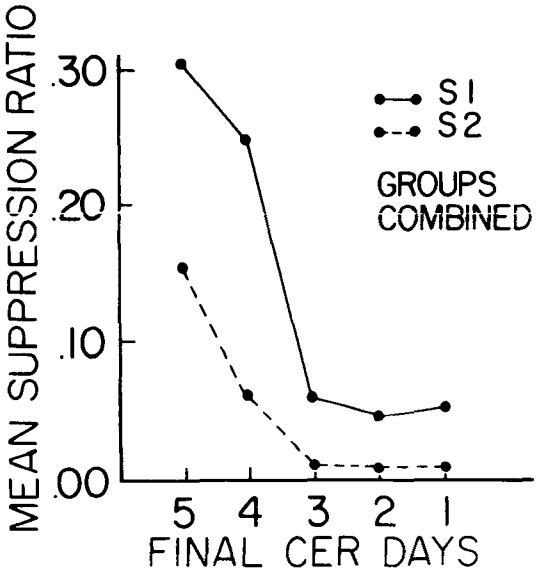

Figure 1. Mean suppression ratios during the last 5 days of CER training.

Table 1
Mean Suppression Ratios During CER Training and the Test Situations

Stimulus	Condition			Test		
	1	2	3	1	2	3
1	.051		.059	.076		.011*
2	.003	.005	.005	.444*	.442*	.416*

Note–CER ratios (Conditions 1, 2, and 3) were computed during the final training day.
**p < .01 (Wilcoxon signed ranks test)*

The results of Test 2, when S2 was presented alone, again showed little evidence of the independent suppressive qualities of this stimulus. S2, when presented alone, indicated a mean ratio of .442.

The results of Test 3, when the S1-S2 sequence was presented in a reverse order, again showed little suppression to S2 (.416). However, there was a statistically reliable *increase* in S1 suppression from the final training day. While the mean S1 ratio equaled .059 during training, during Test 3, when the occurrence of S1 followed the occurrence of S2, mean suppression during S1 increased to .011.

DISCUSSION

The mean suppression ratios obtained during the final days of CER training confirmed the results of Scheuer and Keeter (1969) as well as those of Ayers (1967). Suppression to S2 was significantly greater than to S1 for each group as well as for both groups combined. No differential effect was found for the specific stimuli used in each element of the compound either during habituation or during training. Since the stimuli used were the offset of ongoing stimulus conditions, rather than the onset of a new stimulus, it is doubtful that any interaction of stimulus elements and apparatus cues occurred.

The test results explicitly demonstrated that the suppression that occurred to S2 was not due either to the discriminative properties of S1 termination or to the *independent* suppressive qualities of S2. This conclusion is drawn from the lack of suppression during the trace interval (Test 1) as well as the relative absence of suppression to S2 when either presented alone (Test 2) or prior to S1 (Test 3).

Since suppression to S2 occurred only when following S1, it appears that the S1-S2 sequence is critical to the promotion of S2 suppression. Thus, S2 suppression was solely a function of the *conditional* discriminative properties of this event occurring following S1. These findings also contrast with Seligman's notion that the suppression qualities of S2 are due to its temporal relationship to shock, independently of S1 occurrence.

We suggest that, rather than considering S2 redundant, it may, instead, be providing information that shock is imminent. Thus, the presence of S1 informs the animal that shock is highly probable and the occurrence of S2 following S1 tells the subject "when shock will occur."

One may, however, criticize the use of the final CER day as the appropriate baseline figure for calculating changes in suppression during testing. Since the test conditions technically involve an extinction trial, one might attribute the loss of suppression during S2 and the trace interval to generalization decrement. This alternative seems highly unlikely for two reasons. First of all, if a generalization decrement was taking place, we would not expect the increase in suppression obtained to S1 during Test 3. Secondly, training trials were interspersed with test trials during the test day. It is therefore unlikely that a generalization decrement would occur on the very first presentation of S2 alone *prior to* shock nonoccurrence.

In conclusion, the results of the present study lend additional support to the information hypothesis as a viable model for determining the conditioned reinforcing properties of stimuli in compound conditioning situations using aversive stimuli. The first stimulus to occur is highly informative. However, the role of S2, not by itself, but conditional upon S1 presentation, may serve to inform the subject as to the temporal occurrence of shock.

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