Negative patterning in classical conditioning: Summation of response tendencies to isolable and configural components*

JESSE W. WHITLOW, JR., and ALLAN R. WAGNER†
Yale University, New Haven, Conn. 06520

Six rabbits were given classical eyelid discrimination training involving "negative patterning," i.e., the reinforced presentation of two isolable cues, A+ and B+, and the nonreinforced presentation of their compound, AB—. The basis for discriminative responding which was thereby produced was evaluated by additionally reinforcing a third single cue, C+, and testing the responding to the novel compounds AC and BC as well as the responding to AB, A, B, and C. Although there was less responding to the nonreinforced compound than to any of the single cues, there was significantly *more* responding to the novel compounds, AC and BC. The results are consistent with the view that component response strengths summate to determine compound responding, but that there are functional, configurational components relatively unique to a stimulus compound.

One of the most common propositions within learning theories (e.g., Hull, 1943; Spence, 1936; Estes, 1950; Konorski, 1948; Rescorla & Wagner, 1972) is that the response-eliciting tendencies of several cues "summate" when the cues are presented in compound. There are clearly instances in which dimensional interactions should preclude such an effect (e.g., Garner, 1970), but there is considerable evidence (e.g., Konorski, 1948; Miller, 1969; Weiss, 1964; Wagner, 1971) that "summation" occurs in classical and instrumental conditioning with a considerable variety of experimentally isolable cues. Indeed, many techniques for evaluating stimulus control are predicated upon some such assumption, even when it is not made explicit.

It is well known, however, that one can deliberately train Ss to behave in a manner apparently inconsistent with a summation principle. Perhaps the most obvious example is to be seen in so-called "negative patterning" (e.g., Woodbury, 1943): If a S is reinforced in the presence of each of two experimentally isolable cues (e.g., A+ and B+) but nonreinforced in the presence of their compound (AB—), it may come to respond to A and to B but not to AB. Since it must be assumed that both A and B have positive response-eliciting tendencies, it is impossible to argue that the lesser response tendency to AB could result from the summation of these tendencies.

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†Requests for reprints should be sent to Allan R. Wagner, Department of Psychology, Yale University, 333 Cedar Street, New Haven, Conn. 06510.

Spence (1952) offered one way to account for such patterning effects and yet maintain the summation principle. Basically, he proposed that A and B when presented together generate additional "pattern" or "configurational" cues (e.g., $\hat{AB}$), the response tendencies to which also enter into the determination of the aggregate tendency to AB. Thus, the response strength (V) to AB might be represented as the summation of V_A, V_B, and $V_{\hat{AB}}$. And, in the negative-patterning case, it could be assumed that $V_{\hat{AB}}$ becomes sufficiently inhibitory (negative) to make V_{AB} less than either V_A or V_B alone. Spence further suggested that if the configurational cues were not very salient in relationship to the remaining components of the compound, their contribution might escape notice in most instances but still allow for pattern responding when made the basis of specific discrimination training.

Granting this interpretation, the experiment to be reported was designed to comment upon the descriptive features that would need to be assumed to characterize the configurational cues in a particular instance of negative patterning. Rabbits were trained in eyelid conditioning with three separate cues drawn from different modalities, each reinforced (A+, B+, C+) and the compound of two of the cues nonreinforced (AB—). After the development of discriminative performance, i.e., responding to the separate cues more than to the compound, Ss were tested on each of the training stimuli and on the novel compounds AC and BC. If the configurational cue, which presumably allows inhibition of responding to AB, were relatively general to like compounds, as compared to single stimuli, e.g., involving the attribute "two-ness" or "more-intense," one would expect responding to AC and BC also to be less than the responding to A, B, or C. Alternatively, if such a configurational cue were relatively specific to the joint occurrence of A and B, one would expect to see evidence in the responding to AC and BC of the summation of the response tendencies to the separate cues. That is, the responding to AC and BC should be greater than the responding to A, B, or C alone.

SUBJECTS

The Ss were six male albino New Zealand rabbits, weighing 2-3 kg at the start of the experiment. All Ss were housed singly and were allowed free access to food and water.

APPARATUS

During training and testing sessions, each S was restrained in a 51 x 18 x 14 cm Plexiglas box through which only its head protruded. The box was set in a 66 x 64 x 53 cm sound-attenuated ventilated chamber completely lined with aluminum foil. The chamber was continuously illuminated by a dim 15-W neon bulb situated behind S, and white noise was always present to maintain a constant sound-pressure level of approximately 74 dB (General Radio sound-pressure meter, 20-kHz scale) as measured at the locus of S's head.

The apparatus permitted both separate and compound presentations of auditory, tactile, and light CSs. The auditory CS was a train of 10/sec clicks at 86 dB, produced by a relay in a sounding box located 25 cm to one side of S's head. The tactile CS was a 60-Hz vibration delivered from a Valmour hand massager, Model 880S, mounted on the floor of the restraining box so as to maintain firm contact with S's chest. The light CS was a train of 20/sec flashes produced by a Grass Model PS2 photostimulator with a nominal intensity setting of 8. The lamp was located behind S and was directed toward the ceiling of the chamber so that flashes were reflected homogeneously from the aluminum-foil lining around S's head. The CS duration was 1,100 msec.

The US was a 100-msec 4.5-mA shock delivered through two stainless steel sutures (Sklar stainless steel surgical wire, No. 32 ga) implanted in the skin about the orbit of one eye. One electrode was approximately .5 cm below the extreme nasal extent of the eye, and one was approximately .5 cm above the extreme lateral extent. The US overlapped the last 100 msec of the CS on reinforced trials, thereby determining a CS-US interval of 1,000 msec.

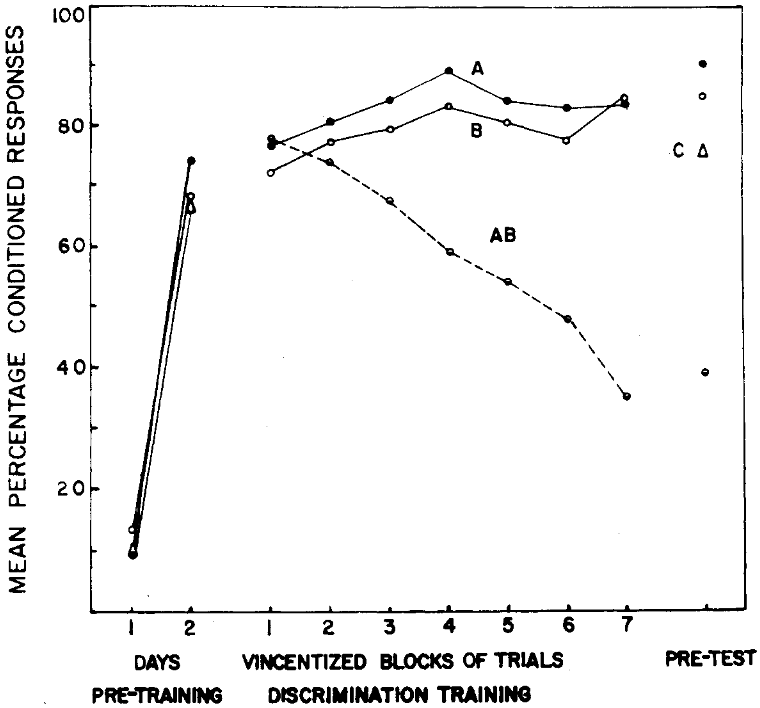

Fig. 1. Mean percentage conditioned responding to CSs A, B, and C and to the compound AB during training. Days 1 and 2 represent 60 and 120 trials, respectively, to each of CSs A, B, and C, while each point in discrimination training represents one-seventh of each S's total trials. The pretest data involve 40 A+, 40 B+, 20 C+, and 80 AB— trials given immediately prior to testing.

Responses were recorded through a microtorque potentiometer that was supported on a small platform taped to S's shaved head. A piece of surgical thread was taped to the upper lid of one eye and anchored to a counterweighted flywheel fixed on the axle of the potentiometer. Movements of the lid turned the flywheel, and these signals were amplified and graphically recorded on a Beckman Dynograph. A CR was defined as an eyelid closure of 1 mm or more during the interval from 200 to 1,000 msec after CS onset.

PROCEDURE

On Day 1, S was introduced to the confinement conditions by being placed in the restraining box outside the experimental apparatus. After 2 h of restraint, S's head was shaved and the electrodes were implanted before S was returned to its home cage.

Although the visual, auditory, and vibratory CSs were known to produce approximately equal conditioning when trained alone and similar negative patterning performance when taken in any pairs, one S was assigned to each of the six possible designations of the three as A, B, and C to avoid any possible effects that might be attributed to a particular cue identification.

On Days 2 and 3, Ss received 60 and 120 reinforced trials, respectively, on each single cue, A, B, and C, each CS occurring 12 times within a block of 36 trials. On Day 4, Ss began discrimination training involving reinforced presentations of A and B and nonreinforced presentations of the compound AB. Each daily session consisted of 10 blocks of 32 trials; within each block there were 8 A+, 8 B+, and 16 AB— trials in a pseudorandom order. Daily sessions were run until S reached a discrimination criterion of greater than 40% fewer responses to AB than to either A or B. On the day after S reached criterion, the C cue was reintroduced by interspersing 4 C+ trials among the 32 trials of a usual training block. Five blocks of such trials were given, followed immediately by testing.

Testing involved the nonreinforced presentations of A, B, C, AB, AC, and BC an equal number of times. The stimuli were presented in six blocks of six trials, such that within each block each cue occurred once and over the six blocks the first-order sequential probabilities were approximately balanced.

RESULTS

Acquisition of conditioned responding to each of the single cues identified as A, B, and C during the first phase of training was approximately equal; the mean percent CRs to A, B, and C were 74.2, 67.9, and 67.6, respectively, on the second day of training.

All Ss learned the negative patterning discrimination in the second phase of training, although the range of number of daily sessions required to meet criterion was substantial, varying from 6 to 33 days (mean = 14.1). An overall picture of learning was obtained by Vincentizing the discrimination learning curves. For each S the total number of blocks of trials was divided into seven equal groups and the percentage CRs within each was computed. The mean percentage CRs in each Vincentized block are presented graphically in Fig. 1. As may be seen, learning consisted largely in a steady decrease in responding to the compound, while a high level of responding was maintained to the single cues; this pattern agrees with that found by Woodbury (1943).

The C cue did not appreciably lose its strength over the course of discrimination learning, during which it was absent, as can be seen by comparing the level of responding to C on the second day of training to that during the five blocks of pretest trials when C was reintroduced.

The data of particular interest are the test data comparing the responding to the novel compounds AC and BC with responding to the training stimuli. Figure 2 presents the mean percentage conditioned responses given on the first three test trials to each of the separate cues and each cue combination. As was the case in training, the nonreinforced AB compound was responded to less than any of the single cues, A, B, or C. The important observation is that the responding to AC and BC was quite different from that to AB, being *greater* than that to any of the single cues. The overall difference in conditioned responding among the several test stimuli was highly significant [$F(5,25) = 7.59$, $p < .001$]. Subsequent comparisons between individual means revealed no significant differences among A, B, and C but reliably less responding to AB than to either AC or BC ($t = 5.43$, $p < .001$, and $t = 5.07$, $p < .001$, respectively). The responding to AB was significantly less than to either A or B ($t = 2.90$, $p < .005$, in each case). In contrast, the responding to AC and BC was either reliably greater than the responding to their separable constituents (with AC vs A or C, $t = 2.54$, $p < .01$, and $t = 1.81$, $p < .05$, respectively; with BC vs B, $t = 2.17$, $p < .025$) or, in one case, approached such level (with BC vs C, $t = 1.45$, $p < .10$).

This same general picture was

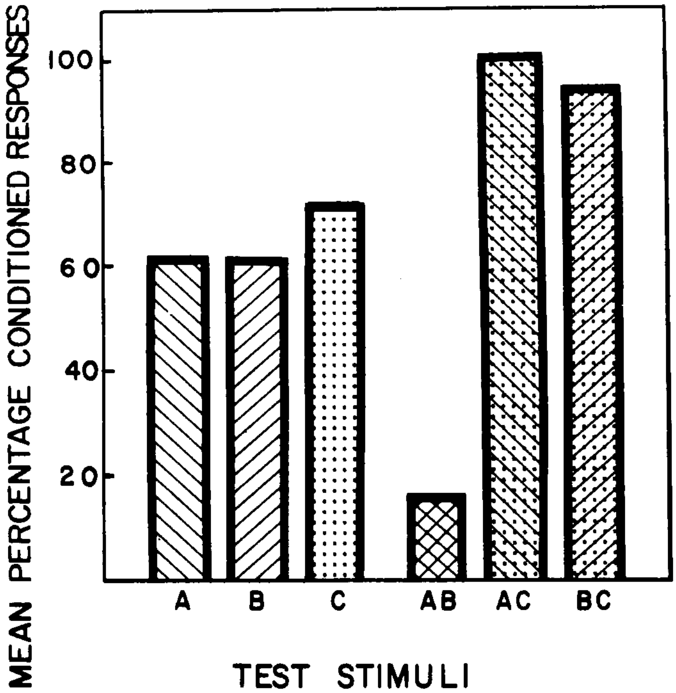

Fig. 2. Mean percentage conditioned responses to CSs A, B, and C and to the compounds AB, AC, and BC during the first three test trials to each cue.

evident as responding extinguished over testing. Thus, for example, an alternative measure based upon number of trials to an extinction criterion led to the same conclusions.

DISCUSSION

Spence's theoretical proposal (1952) concerning pattern discrimination learning is silent with respect to the descriptive features of the configurational cues assumed to be involved. This becomes an empirical question in any situation. The obvious implication of the present study is that under the conditions employed, involving isolable cues in different modalities, negative patterning was not based upon a configurational cue common to the several compounds, i.e., upon such potentially available cues as "two-ness" or "more-intense." Rather, among the several test conditions, responding was seen to be inhibited only during the joint presence of A and B. This implicates a configurational cue relatively unique to the nonreinforced compound, but still leaves a fuller description of its features for more comprehensive evaluation.[1]

Of more general significance is the fact that even when Ss are trained not to respond to one compound of otherwise reinforced cues, they may still evidence a summation of response tendencies to these and other separate cues in different aggregations. Even when S is deliberately trained with one set of stimuli so as to behave in apparent conflict with the summation principle, its behavior with respect to other stimuli attests to the general viability of the principle.

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NOTE

1. Rescorla (in press) has obtained similar findings in a discrete-trial barpress situation with a different set of cues, suggesting some degree of generality for this conclusion.