"CONFIGURAL" CONDITIONING IN DISCRETE-TRIAL BAR PRESSING

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Three experiments are reported comparing responses to stimulus compounds and to their elements. Experiment 1 found no loss in responding to the elements of a repeatedly reinforced stimulus compound. Experiments 2 and 3 explicitly trained a discrimination between a compound and its elements and found successful learning whether the compound or the elements were reinforced. Addition of an explicit stimulus common to the compound and its elements retarded, rather than facilitated, the discrimination. Replacement of one element in a compound by another of similar intensity and associative strength disrupted performance. These findings rule out a number of interpretations of "configuring," but permit an interpretation in terms of a unique stimulus element and limitations on the total associative strength of the compound.

An elementary problem in the development of any theory of behavior is that of providing an account of the response to a stimulus complex in terms of the responses to the elements of that complex. If an organism exhibits a learned response to a stimulus compound, AB, how can we understand this response in terms of the learning to the individual elements, A and B? Most theories (e.g., Estes, 1950; Hull, 1943) assume that the response to the compound is some combination of the learning to the elements. Indeed, a common specific combination rule has been proposed: that the "associative strength" of the compound is simply the algebraic sum of the associative strength of the elements.

Such combinatorial approaches have much to recommend them. For instance, innumerable experiments indicate that if a conditioned response is separately established to A and to B, then the AB compound will evoke a response greater than that observed to either element (e.g., Konorski, 1948; Pavlov, 1927; Weiss, 1964). Furthermore, if A is trained as an evoker of a CR while B is trained as an inhibitor, the response to AB will be less than that to A alone (Konorski, 1948; Rescorla, 1969).

But despite these supporting results, a number of lines of evidence seem inconsistent with a simple combinatorial approach. Most notable is the suggestion that in certain experimental paradigms "configural" conditioning occurs, resulting in a response to AB which is not interpretable in terms of a combination of the associative strengths of A and B. Three such paradigms have commonly been employed.

1. Repeated reinforced presentation of an AB compound. Some authors have claimed that when a compound is repeatedly reinforced, eventually the response to the individual elements will decline and even approach zero (cf. Razran, 1965). If the response to the compound remains high while that to the elements diminishes, it seems difficult to account for behavior to the compound in terms of that to the elements.

2. Discrimination between the compound and its elements. Instead of simply reinforcing an AB compound and occasionally examining the elements, one can explicitly train responding to the compound while nonreinforcing the separately presented elements. Woodbury (1943) has provided some evidence that with such training dogs will eventually respond to AB but not to A or B. Similarly, they may be trained to respond to the elements but not to the compound. Such outcomes seem difficult for any attempt to explain the learning to the comp-
pound purely in terms of that to the elements.

3. Conditional discrimination. Consider a learning situation involving four cues, presented in pairs and reinforced as follows: AC+, BD+, AD−, BC−. In such a procedure, each cue is individually reinforced on half its occurrences and nonreinforced on the other half. Although there is very little data on this kind of procedure, it appears that in some situations animals are capable of learning to respond to AC and BD while withholding their response from AD and BC (e.g., Saavedra, 1971). It is again difficult to see how an account of compound responding purely in terms of the learning of the elements can encompass this outcome. It should especially be noted that all three types of experiment present problems for many combination rules, not simply for an “additive” rule.

The experiments reported here are concerned with the first two lines of evidence. Experiment 1 explores whether configural conditioning occurs with simple repeated reinforcement of a compound in a discrete-trial bar-press situation. Experiments 2 and 3 examine alternative interpretations of the results of training a discrimination between a compound and its elements, interpretations consistent with a general combinatorial approach.

EXPERIMENT 1

In a recent review, Baker (1968) has found little evidence for loss of responding to the elements, A and B, when the AB compound is repeatedly reinforced. Indeed, he noted that the proper experiment has seldom been performed, since most investigators use a within-subjects design, resulting in repeated nonreinforced testing of the elements. Such a procedure may yield results relevant to Paradigm 2 above, but cannot provide unequivocal results for Paradigm 1. When a more appropriate between-subjects design was employed, Baker (1969) found no evidence for loss in responding to the elements in eye-blink conditioning. However, other results (e.g., Booth & Hammond, 1971) suggest that configural conditioning may occur with this paradigm in a conditioned suppression situation. Experiment 1 was designed simply to provide evidence on another situation, discrete-trial bar pressing.

Method

Subjects and apparatus. The subjects were 16 Sprague-Dawley male rats about 100 days old at the start of the experiment. They were maintained throughout the experiment at 80% of their normal body weight.

The experimental chambers were four identical Skinner boxes 9 × 8 × 8 in. Each chamber had a recessed food magazine in the center of the end wall and a bar to the left of the magazine. The floor of the chamber was composed of 3/16-in. stainless-steel rods, spaced 1/4 in. apart. The two end walls were aluminum; the side walls and top were clear Plexiglas. Each Skinner box was enclosed in a sound- and light-resistant shell. Mounted on the rear wall of this shell was a 6/2-w. light, a speaker, and a relay clicker. The speaker permitted the presentation of a 1,200-Hz. tone and the clicker operated at a rate of 2/sec. Experimental events were controlled and recorded automatically by relay equipment located in an adjoining room.

Procedure. In the first session each rat was magazine trained automatically with food pellets (45 mg., P. J. Noyes Co.) delivered on a VI 1-min. schedule. In addition, each bar press yielded a food pellet. This session continued until each rat had emitted about 50 bar presses; shaping was used if necessary.

For the next 11 days, all subjects received pretraining with a discrete-trial procedure in which trials were signaled by a 1/sec flashing of the houselight. Responses terminated the light and delivered a food pellet; failures to respond within 15 sec. of light onset resulted in its nonreinforced termination. On the first 7 such pretraining days, 120 trials were administered with a mean intertrial interval of 1 min. For the final 4 pretraining days, 60 trials were given with a mean intertrial interval of 2 min. The object of this pretraining phase was to reduce intertrial responding before beginning compound training. Since the intention of the experiment was to test element responding as compound training proceeded, it is important that such element responding not be confounded with changes in intertrial behavior not under stimulus control.

On the next day, discrete-trial training began with the tone and clicker in compound signaling the availability of food. Sixty trials were given each day with a mean intertrial interval of 2 min. Short tests of the tone and clicker were introduced into the middle of some training sessions. On each such test, five tones and five clickers were presented, each for a maximum of 15 sec. Responses terminated these stimuli, but no reinforcements were delivered. The animals were divided into four groups, designed to permit testing of the elements
after four levels of compound training. A “peel-off” procedure was used such that one group received its first test after each of four levels of compound training; but, in addition, groups first tested at low levels of training were tested again after additional training. Thus, animals in Groups 90, 270, 570, and 1,170 each received their first test after the number of compound trials used to designate the group, but once tested a group received all subsequent tests. This procedure permits comparison of animals tested for the first time with animals previously tested, at the various levels of training. Should prior testing have little effect, considerable economy can be gained in data collection.

Results and Discussion

Figure 1 shows separately for the tone and clicker the percentage of test trials producing responses in the various groups. Response latencies were also examined, but since most responses occurred immediately after trial onset, they provide little additional information and will not be presented. The pretraining to the light successfully reduced intertrial responding so that through the testing periods intertrial responses averaged fewer than 1/min. Furthermore, responding was rapidly acquired to the tone-clicker compound; failures to respond to the compound were virtually absent by the first test session. Consequently, the data in Figure 1 all come from periods of strong compound responding and low intertrial responding.

As may be seen, the clicker consistently produced more responding than did the tone. However, both stimuli continued to produce a considerable amount of behavior.

![Figure 1](image-url)
throughout the various stages of compound training. In fact, responding to the tone showed a slight, but nonreliable, increase over trials. This is partly due to a tendency for the group receiving its first test at a given point to show less responding than other groups tested at the same stage of training. Apparently a small amount of prior testing with the components did not result in extinction, but rather in reduction of the disruptive effects of presenting a novel stimulus.

As a further check on the stability of responding to the components, the two groups first tested after 570 and 1,170 trials were each given 600 additional compound training trials and tested again. The mean percentage of test trials producing a response was 75 for the tone and 90 for the clicker. These results indicate that even after 1,770 trials responding to the elements remained high. Perhaps with yet further training such responding would decline; but considering that responding to the compound was very strong after only 90 trials, the amount of training used here seems quite large. It seems reasonable to conclude that in the present situation configurational conditioning does not result from simple repeated reinforcement of a stimulus compound.

**Experiment 2**

Although the previous experiment indicates that configurating may not occur "naturally" in the bar-press situation, it remains possible that a discrimination could explicitly be trained between a compound and its elements (cf. Woodbury, 1943). Experiment 2 was designed to explore this possibility. In addition, this experiment attempted to explore two alternative interpretations of configuring which are compatible with a general combinatorial approach.

First, most workable combination rules have the property that the response to AB is greater than that to each of the individual elements, if those elements have positive associative strength. Furthermore, it seems reasonable to assume (e.g., Hull, 1943) that for a stimulus to evoke behavior, its associative strength must exceed some threshold level. Consequently, in a discrimination in which AB is reinforced but its elements nonreinforced, it is possible that although the elements have associative strengths below threshold, the compound nevertheless exceeds that threshold. Thus, differential responding would be possible in that situation even with a simple additive combination rule. However, this argument seems implausible for the alternative discrimination in which the elements are reinforced but the compound nonreinforced, AB−, A+, B+. Therefore, this more powerful discrimination procedure was chosen for investigation.

Second, Rescorla and Wagner (1972) have recently advanced a general theory of the operation of reinforcement in Pavlovian conditioning. According to that theory, the effect of a reinforcement or nonreinforcement in changing the associative strength of an element of a compound depends upon the total associative strength of that compound. In addition, they suggest that the elements themselves are conceptually divisible into subparts. Some of the elements may have subparts in common; an obvious possibility is that the various elements share an "onset" property. It then becomes reasonable to represent the elements as AX and BX, so as to acknowledge their separate (A and B) and common (X) properties. The compound would then be represented as ABX. Rescorla and Wagner (1972) demonstrate that their model, which assumes strict additivity of associative strengths, can generate learning of a discrimination between elements and compounds so conceptualized. For instance, in the case of ABX−, AX+, BX+, the common cue, X, should acquire considerable associative strength, while the A and B elements should become inhibitors. Equally important, according to this approach, the more salient is the common X cue, the easier should be the acquisition of that discrimination. Although all compounds can be conceptualized as having an X, the salience of that common cue can be enhanced by the addition of an explicit experimentally manipulable X. Rescorla and Wagner (1972) appear to make the implausible prediction that such an addition of a stimulus common to the
elements and to the compound should facilitate the discrimination. On the assumption that their reasoning for Pavlovian conditioning has some analogous implications for instrumental training, this prediction was tested in the present experiment.

Method

Subjects and apparatus. The subjects were 16 male Sprague-Dawley rats about 100 days old at the start of the experiment. They were maintained throughout the experiment at 80% of their normal body weight. The apparatus was identical to that of Experiment 1.

Procedure. The animals were bar-press trained as in Experiment 1. They then received discrete-trial bar-press training in which 120 trials were administered on each with a mean intertrial interval of 1 min. Forty trials of each day were nonreinforced compound trials, 40 were reinforced presentations of one element, and 40 reinforced presentations of the other element. The maximum trial length was 15 sec.; response terminated the stimulus and, when appropriate, delivered a food reinforcement. Group AB—received compound trials consisting of a tone and clicker as well as element trials consisting of their separate presentation. Group ABX—received the same events, except that a flashing houselight (X) accompanied each trial. Both groups received 1,800 trials of this discrimination procedure.

Following this training, Group ABX—received a test day designed to assess responding to the elements. On that day, the first 60 trials continued discrimination training. Then the subjects received five nonreinforced trials each with the light, tone, clicker, and tone-clicker compound, with a mean intertrial interval of 1 min. Maximum trial duration was 15 sec.; responses terminated the stimulus but were not reinforced with food pellets.

Results and Discussion

Figure 2 shows the mean percentage of trials on which the animals responded, in blocks of 60 total trials. Although intertrial responses initially grew, they rapidly dropped off to essentially zero. It is clear from the figure that in both groups the discrimination did develop over the course of training. By the last day of training only one animal failed to make fewer responses to the compound than to its elements. It is also clear that the discrimination developed quite slowly and was mainly of the form of learning to withhold responses to the compound. Furthermore, Group AB—developed the discrimination earlier and to a greater degree than did Group ABX—. On the final day of training, Group AB—gave reliably fewer responses to the compound than did Group ABX— (Mann-Whitney U = 9, p < .01).

The fact that discrimination developed with this particular procedure seems difficult to reconcile with a simple threshold notion of such discrimination. Furthermore, the superiority of Group AB—directly contradicts the argument in terms of common elements given by Rescorla and Wagner (1972).

Because the latter approach also makes predictions about element responding, Group ABX—was tested for responding to the elements following discrimination training. The mean percentage of trials on which responses occurred were as follows: light, 80; tone, 49; clicker, 52; and clicker-tone, 20. The superiority of the light over the other components is reliable while they in turn gave more responding than did the compound (Wilcoxon T's < 2, ps < .05). Although the present common-cue application of the Rescorla-Wagner (1972) theory correctly predicts maximum responding to the light, it incorrectly leads to the expectation that the clicker and tone should individually evoke no behavior. Furthermore, that approach predicts that the removal of the light from the various stimuli should greatly reduce the discrimination between compound and elements. There is no evidence that this reduction occurred. Thus, this particular application of that theory appears incorrect; an alternate application which is more successful is discussed later.

Experiment 3

It is apparent from the previous experiment that discrimination between compound and elements is possible in the present situation. Furthermore, attempts to make this compatible with a combinatorial approach by introducing the notions of threshold or common elements do not receive support from that experiment.

There remains, however, an alternative interpretation of these data which would not require abandoning a combinatorial approach. It is possible that we have misidentified the stimulus dimensions to which
the organism is responding. It may make use of stimulus dimensions other than those specified by the experimenter in order to solve the discrimination task. Indeed, it seems possible that such explicit discrimination training forces the subject to abandon the experimenter-defined dimensions precisely because the subject employs a
combination rule making solution of the discrimination impossible along those dimensions. One particularly attractive alternative dimension which the organism may use is the intensity of stimulation on a trial. If the subject solves the discrimination by using the intensity of stimulation on a trial, or the number of stimuli present on a trial, the relevance of such experiments for evaluating general combination rules is less clear. In that case it would be more appropriate to conceptualize the compound and elements as different loci on an intensity continuum, rather than viewing the compound as composed from separable elements. One implication of such a possibility is that following discrimination training, it should be possible to change the specific elements of a compound and not disturb the discrimination performance, as long as intensity or numerosity relations are preserved. This experiment investigates that possibility.

Method

Subjects and apparatus. The subjects were 32 male Sprague-Dawley rats about 100 days old at the start of the experiment. The apparatus was the same as that used in the previous two experiments.

Procedure. All animals were trained to bar press as in previous experiments. They then received discrete-trial training in which the maximum stimulus duration was 15 sec. Responses terminated the stimulus and, on half of the trials, delivered food reward. The animals were divided into four groups of eight each. Groups A1A2+ and A1A2− both received, on each day, 60 presentations of a compound stimulus consisting of two auditory stimuli (tone and clicker) and 20 separate presentations each of the tone, clicker, and flashing houselight. For Group A1A2+ the compound signaled the availability of food reinforcement and the three individual stimuli were nonreinforced; for Group A1A2− the reinforcement contingencies were reversed. Groups A1L+ and A1L− received the same presentation of individual stimuli, but their compound was composed of an auditory and visual element. For half of each group the auditory element was the tone, for the other half it was the clicker.

After 12 days of discrimination training, a single test session was given. The first 60 trials of this session continued the prior discrimination training. The final 20 trials consisted of five nonreinforced presentations of each of the following stimulus compounds: A1A2, A1L, A2L, and A1A1L. Throughout the experiment each trial was of 15-sec. maximum duration, responses terminated the trial, and the mean intertrial interval was 1 min.

Results

Figure 3 shows the acquisition results for the four groups. As in the previous experiment, acquisition consisted primarily of decreased responding to the nonreinforced stimuli. The results for the groups receiving the purely auditory compound and those receiving the auditory—visual compound seem quite similar. In both cases, when the elements were nonreinforced, that element not also present during the compound was the most rapid to extinguish (Ts = 0, ps < .01). Also for both cases the discrimination proceeded more rapidly when the compound was reinforced than when it was nonreinforced. By Day 5 of training, the compound evoked more responding in Groups A1A2− and A1L− than did the most—responded—tr to element in Groups A1A2+ and A1L+ (U = 4, p < .01).

Figure 4 shows the mean percentage of trials on which responses occurred over the last 30 training trials and the 20 nonreinforced test trials. For each group, the first stimulus plotted in each set was observed in both training and testing. In all cases there was only a small decrement in responding to that stimulus, suggesting that behavior remained stable over the testing sequence.

For each group, testing involved, in addition to the presentation of the training compound, two novel compounds, each containing only one of the stimuli from the training compound; these are the next two compounds plotted for the test session. In Groups A1L+ and A1A2+ there was relatively little responding to these novel compounds, despite substantial responding to the training compound. In Groups A1L− and A1A2−, the novel compounds evoked considerable responding while the training compound continued to produce little behavior. In each case the difference between novel and training compounds was reliable (Wilcoxon Ts < 2, p < .05). Responses to the novel compounds were similar to those evoked by the individual elements, rather than to the training compounds.
The final data in each set of testing results are from presentation of the triplet, A₁A₂L. In all four groups this novel compound evoked considerable responding. Thus, in the compound-reinforced groups the triplet evoked behavior similar to that of the original training compound, whereas in the compound-nonreinforced groups the triplet produced behavior similar to that evoked by the elements.

Discussion

This experiment provides another example of the rat's ability to respond differentially to a compound and its elements. But more importantly, it provides some information on how this discrimination is accomplished. First, it is of interest to note that whether the stimulus elements were in the same or in different modalities, the discrimination proceeded similarly. This suggests that in the present situation elementary stimulus interactions resulting from concatenation of stimuli (such as auditory beats or difference tones) are not central to the discrimination. Second, the differential responding of all four groups to the training and novel compounds suggests that stimulus dimensions such as overall intensity of stimulation or number of stimuli present...
are not the basis of the differential behavior. Apparently, the rat is sensitive not only to the intensity but also to the content of the compound.

A number of theoretical alternatives yet remain to that of abandoning the general combinatorial approach for generating behavior to the compound on the basis of that to the elements. One possibility is that although, in many situations (such as summation tests), the organism uses a relatively simple combination rule, it nevertheless has a variety of other combination rules which it may employ if special discriminations force their use. It is, of course, possible to generate combination rules which would predict accurately the outcomes of experiments like those predicted here. However, this alternative is relatively unattractive without some specification of the class of rules employed, the conditions under which various ones are selected, and description of a mechanism by which the organism makes that selection. Furthermore, the third experiment places constraints on the form of the rules which might be successful. Notice that the separate stimulus elements have quite comparable associative strengths. Yet substitution in the compound of a novel element for an element of the same associative strength yielded a substantial difference in behavior. This strongly suggests that in combining different stimuli, whatever rule is employed, the organism must make use of information other than simple individual associative strengths. The same associative strengths become combined to yield quite different results. Consequently, whatever combination rules are employed must somehow be specific to the identities of the particular stimuli. This makes the use of alternative combination rules an even less attractive theoretical alternative.

A second avenue of conceptualization has been suggested by Wagner (1971) and Wagner and Rescorla (in press). One might suppose that stimulus compounds should be treated as the combination of their elements plus some stimulus which is uniquely generated whenever those elements are presented together. The associative strength of a two-element compound would then be a combination of three associative strengths, one from each of the elements and one from that unique stimulus. On this scheme, the compound does represent something beyond the elements, but does not involve destruc-
tions of the integrity of those elements when presented in compound. Such a combination rule would permit an account of the results of the large number of summation experiments which appear to support a combinatorial approach.

If combined with the general model of conditioning proposed by Rescorla and Wagner (1972), this unique stimulus assumption is also capable of providing an account of many of the present results. According to that model, the total associative strength of all elements in a compound preceding a reinforcement approaches an asymptote determined by that reinforcement. Similarly, the total associative strength of elements in a compound preceding nonreinforcement approaches an asymptote of zero. Accordingly, in the case of an AB+, A−, B− discrimination, the individual elements, A and B, would attain no associative strength while an element uniquely present during the compound would attain considerable strength. Indeed, it would account for all of the learning. Similarly, in the case of an AB−, A+, B+ discrimination, the individual elements would become strong and the unique element would become sufficiently inhibitory to overcome their sum in the compound. If the relative salience of that unique element is low, we would expect learning of such discriminations to be difficult. Furthermore, the need for the unique element to develop the more slowly learned inhibition in Group AB− (cf. Rescorla & Wagner, 1972) may account for the slower discrimination learning in that condition.

If the stimulus unique to the AB compound is not present during the novel compounds of Experiment 3, we would also anticipate the results observed to those compounds. Thus, in the case of an AB+, A−, B− discrimination, since the unique stimulus carries the associative strength, we would not anticipate behavior to the novel compounds. Similarly, in the case of an AB−, A+, B+ discrimination, the novel compounds would not contain the necessary inhibitory stimulus and would thus be expected to produce responding. Furthermore, the triplet should produce responding in both paradigms. In the case of AB+, the triplet contains the unique stimulus plus three low-strength stimuli; in AB−, the triplet contains the inhibitory unique stimulus, but it additionally has three stimuli each with high associative strength.

Two further points are worth mentioning about this approach. First, in the case of simple repeated reinforcement of AB, it does not predict configuring. The individual stimuli will acquire associative strength up to some asymptote, with the unique stimulus presumably acquiring some relatively small portion of the strength. But there is no reason to anticipate that the strength of the elements should change over trials, either relative to one another or in absolute level. With the bar-press situation, Experiment 1 agrees with those predictions.

Second, the simple assumption that the compound contains the elements plus a unique stimulus is not by itself sufficient to generate discrimination in situations like AB+, A−, B−. Since A and B are reinforced on a 50% schedule, within most theories they should maintain behavior at a moderately high level. The situation is analogous to one in which AB is reinforced and A nonreinforced. Rescorla and Wagner (1972) discuss such cases and indicate how an assumption of a limitation on the total associative strength of a compound generates the prediction that A will lose all associative strength despite the receipt of reinforcement on half of its occurrences. But some such assumption is necessary for marked reductions of that sort to occur; the simple presence of a unique stimulus is not sufficient.

The experiments reported here suggest that several possible approaches to the salvaging of a combinatorial approach in the face of configural data are unlikely to be successful. However, the assumption of a unique compound stimulus, taken together with an assumption about limitations on the total associative strength with which reinforcement can endow a compound, does provide an adequate account of these data. While the latter assumption has been examined extensively in a number of Pavlovian settings (cf. Rescorla, 1970; Rescorla &
Wagner, 1972; Wagner, 1971; Wagner & Rescorla, in press), the assumption of a unique stimulus still awaits further direct experimental testing.

REFERENCES


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