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Cue Relevance as a Continuum

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CUE RELEVANCE AS A CONTINUUM

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CUE RELEVANCE AS A CONTINUUM

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B.A., University of Colorado, 1970

THESIS

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CUE RELEVANCE AS A CONTINUUM

By

David A. Governski

ABSTRACT OF THESIS

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CUE RELEVANCE AS A CONTINUUM

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The primary purpose of this experiment was to demonstrate how different percentages of reinforcement can result in differential amounts of stimulus control. The initial conditions were designed to see if organisms could distinguish between different reinforcement percentages of different stimuli, even though these stimuli always appeared in compound and never in isolation.

In Condition I, four stimuli were used with the following absolute reinforcement percentages: 75, 75, 50, and 0, corresponding to three different tones and a light. Results showed that the light had become a conditioned inhibitor but that no difference in stimulus control was obtained between the 75% and 50% reinforced stimuli. Condition II showed that when reinforcement percentages were changed to 75, 75, 25, and 0, a difference in percent responding between 75% and 25% reinforced tones could be obtained. The light again demonstrated strong controlling properties as a conditioned inhibitor. Due to discrepant results in the first two conditions, and due to the strong effect of the light as a conditioned inhibitor, only three stimuli were used in Condition III, where reinforcement percentages were 75, 75, and 50 for three tones. Data analysis indicated a significant difference between response percentages of 75% and 50% reinforced cues. Acquisition data demonstrated that the task was difficult and the discrimination poor. Condition IV examined the effect of different percentages of reinforcement on two stimuli in the same modality. Results showed that whether the discrimination between a 75% and 50% reinforced cue was obtained depended upon the physical similarities and differences of the tones. Large differences were obtained when stimuli were farther apart in intensity. Condition V investigated these same reinforcement percentages with stimuli in two different modalities. Large differences in stimulus control were obtained.

Results from all five conditions indicate that cue relevance may be viewed as a continuum, but that differences in stimulus control also depend on the number of stimulus modalities involved, the differences and similarities of stimuli, and their saliencies. Furthermore, a conditioned inhibitor was demonstrated for the first time within an instrumental appetitive conditioning paradigm.

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INTRODUCTION

Assuming no previous reinforcement history, a stimulus gains control over responding (or not responding) by conveying information about the occurrence (or nonoccurrence) of emotionally significant events. The simple case of a single stimulus gaining control over responding has been demonstrated in classical, operant, and instrumental conditioning. But, in many situations, single stimuli are not presented in isolation. Rather, a stimulus is often compounded with a second stimulus such that the control gained by one stimulus depends upon the information conveyed by that stimulus and the information conveyed by the second stimulus. For example, a stimulus that is an imperfect predictor of reinforcement gains little or no control if compounded with a perfectly valid predictor of reinforcement (Wagner, Logan, Haberlandt, & Price, 1968), and conversely, a stimulus that is an imperfect predictor of reinforcement does gain control over responding if compounded with a perfectly valid predictor of nonreinforcement (which becomes a conditioned inhibitor, Governski, Conditions I and II).

The concept of the amount of information conveyed by any cue is essential to any theory of discrimination learning. Those stimuli which convey the most information about the occurrence of emotionally significant events are the stimuli to which an animal learns to respond. A stimulus can convey information about the type of reinforcement, the quality of reinforcement, its delay, and, of course, the number of times reinforcement (or nonreinforcement) follows the stimulus. It is to this latter bit of information to which this thesis is addressed.

The two previous examples of differential reinforcement represent the extremes of a continuum of reinforcement percentages. In one case, a stimulus reinforced 100% of the time (a perfect predictor of reinforcement) gains more control over responding than a stimulus reinforced less than 100% of the time. The second example covers the case in which a stimulus, reinforced some percentage of the time, is responded to more frequently than a stimulus which conveys the information that no reward is forthcoming. Thus, a perfect predictor of reinforcement and a perfect predictor of nonreinforcement are highly informative cues on which the animal could base his responding or not responding.

With the basic thesis being that the percentage of reinforcement is an important bit of information which can be conveyed by a stimulus, a series of experiments can be designed to assess the amount of stimulus control acquired by stimuli varying in percentages of reinforcement. The question asked here is: Does a continuum of stimulus control based on different reinforcement percentages exist?

The experimental literature concerned with discrimination learning shows that percentage of reinforcement is a frequent manipulation from which stimulus control is often assessed. However, the wide variety of experimental conditions used have tended to confound the testing of the above experimental question. An attempt to answer the question can be simplified if restrictions are placed on experimentation.

It is the intention of this thesis to deal with only a small subset of the number of stimuli which may be presented by the experimentor. Discussion and experimentation will be confined to those cases in which only two, three, or four stimuli may be presented. Furthermore, these stimuli may occur by themselves or in compound with only one other stimulus.

A second restriction is the requirement that stimuli occur in a random order. Presenting stimuli in a random order eliminates a large portion of literature within the discrimination learning area concerned with stimulus pretraining; that is, any exposure to a stimulus prior to discrimination training with other stimuli. This restriction reduces some complications due to the history of stimulus presentation.

A final important restriction concerns the number of stimulus modalities. Most experimentation has been performed using only one or two modalities. A modality restriction is necessary not only for simplicity but also because the effect of modality upon percent reinforcement has been relatively unexplored. Perhaps stimulus modalities may affect discrimination learning by increasing or decreasing cue saliency. For example, the discrimination between two stimuli in two different modalities may show large differences in responding when the modalities are those frequently used, or small differences when the modalities are those not so frequently used. It is the intention of this thesis to confine discussion to only one or two stimulus modalities and to point out how the modality selections have affected the reinforcement manipulation in the following experimental conditions.

Tables 1, 2, and 3 are intended to point out examples of research already completed under the above restricted conditions. The left-hand column of the tables specifies the conditions of the percentages of reinforcement for each of the stimuli: S_1, S_2, S_3, and S_4. For example, 100, 50, 50, 25 refers to an experimental condition in which S_1 is reinforced 100% of the time; S_2, 50% of the time; S_3, 50% of the time; and S_4, 25% of the time. The reinforcement percentages are represented under the appropriate stimulus according to the number of reinforced trials over the number of nonreinforced trials. Such percentages have been defined using a hypothetical 100 trials (± 2). A 50% reinforced stimulus may be represented by 50/50, meaning 50 trials of reinforcement and 50 trials of nonreinforcement. Finally, the outcome for each row of different reinforcement percentages is either predicted or summarized in the right-hand column.

Two Stimulus Case

Table 1 displays several examples of the two stimulus case. In the simple discrimination problem (line 1), the animal learns to respond to S_1 (100% reinforced) and not to respond to S_2 (0% reinforced). However, both S_1 and S_2 are presented as isolated stimuli. The complexity imposed by compounded stimuli is introduced in lines 2 and 3. Both S_1 and S_2 are perfectly valid cues in predicting reinforcement, yet different amounts of control may be observed. An example of differential control for two perfect predictors of reinforcement was demonstrated by Wagner (1969). Wagner showed that if only S_1S_2 is presented during training, S_1 and S_2 during testing are essentially equally valid cues. However, if S_1S_2 trials are interspersed with S_1 trials during training, S_1 gains more control over responding than S_2 in subsequent tests for stimulus control. Similarly, differential control is shown in the case where S_1 and S_2 have a validity of 100% and 50% respectively (lines 4 and 5). S_1 gains more control over responding than S_2 if S_2 is nonreinforced when presented alone but always reinforced when presented in compound with S_1 (line 4, Wagner, 1969).

Other possibilities of the two stimulus case may be examined by pairing different reinforcement percentages and then assessing the

Table 1

Two Stimulus Case

	% REINFORCEMENT				STIMULI = # REINFORCED TRIALS/# NONREINFORCED TRIALS										OUTCOME
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1S_2	S_1S_3	S_1S_4	S_2S_3	S_2S_4	S_3S_4	Predicted and/or completed experiments
1.	100	0	X	X	$\frac{50}{00}$	$\frac{00}{50}$	X	X	X	X	X	X	X	X	Simple discrimination problem. S_1 more control.
2.	100	100	X	X	X	X	X	X	$\frac{100}{000}$	X	X	X	X	X	$S_1 = S_2$ in control.
3.	100	100	X	X	$\frac{50}{00}$	X	X	X	$\frac{50}{00}$	X	X	X	X	X	Wagner (1969) $S_1 > S_2$.
4.	100	50	X	X	X	$\frac{00}{50}$	X	X	$\frac{50}{00}$	X	X	X	X	X	S_1 gains more control.
5.	100	50	X	X	$\frac{33}{00}$	$\frac{00}{33}$	X	X	$\frac{33}{00}$	X	X	X	X	X	S_1 should gain control.
6.	75	50	X	X	$\frac{37}{12}$	$\frac{25}{25}$	X	X	X	X	X	X	X	X	S_1 should gain control.
7.	75	50	X	X	$\frac{33}{00}$	$\frac{17}{17}$	X	X	$\frac{17}{17}$	X	X	X	X	X	$S_1 > S_2$, but S_1S_2 may show control over S_2.
8.	75	50	X	X	$\frac{00}{16}$	$\frac{00}{42}$	X	X	$\frac{42}{00}$	X	X	X	X	X	*Proposed conditions. Conditions IV and V.
9.	50	0	X	X	$\frac{50}{00}$	X	X	X	$\frac{00}{50}$	X	X	X	X	X	Wagner (1971), Rescorla (1971). S_2 gains inhibitory properties.

amount of stimulus control gained by each stimulus. However, a stimulus may not only gain control over responding but may also gain control over the response of "not responding." An example of the latter case (line 9) has been demonstrated by Rescorla, 1971; Rescorla and Wagner, 1972; Wagner, 1971; and Wagner and Rescorla, 1972. Wagner and Rescorla demonstrated that a stimulus which was never reinforced when compounded with a second cue (always reinforced in isolation) developed conditioned inhibitor properties; i.e., tended to suppress responding to a second stimulus.

In assessing the amount of stimulus control in the two stimulus case, a 100% reinforced stimulus should gain more control over responding than a 0% reinforced stimulus. Similarly, a 100% reinforced stimulus should gain more control over responding than a 50% reinforced stimulus. Continuing this type of paired comparison, a stimulus which has been reinforced a higher percentage of time should gain more control over responding than a stimulus reinforced a lower percentage of time. However, the difference in the amount of control between two stimuli also depends on the stimulus modalities being used. For example, the discrimination between a 100% and a 0% reinforced stimulus would not be as difficult if stimuli are in one dimension compared to the difference between a 75% and a 50% reinforced stimulus in the same dimension. In other words, there seems to be a complex interaction between reinforcement and stimulus modalities.

In summary, the two stimulus case shows that the amount of stimulus control gained by one stimulus is affected by the information supplied by another stimulus. In the following pages, the three and four stimulus cases will show examples in which stimulus control evidenced by one stimulus depends upon information conveyed by several different stimuli.

Three Stimulus Case

Starting with the simplest case of discrimination learning in the three stimulus case, one stimulus is reinforced 100% of the time, and the other two stimuli are reinforced 0% of the time (line 1, Table 2). Table 2 (lines 2 and 3) demonstrates two other ways to obtain a discrimination with one stimulus (100% reinforced) and two other stimuli (0% reinforced). In line 2, S_1 is always reinforced, and the compound S_2S_3 is never reinforced. S_1 would be expected to gain control over responding. But S_2 and S_3 may also evoke some responding, when presented alone, due to generalization of responding to single stimulus presentations. Line 3 demonstrates one way to control for generalization to single stimulus presentations, and that is to present all stimuli alone at some time during training. As in the two stimulus case, a continuum of stimulus control may exist for three stimuli. Differential stimulus control for three stimuli can be obtained by reinforcing one stimulus 100% of the time, by reinforcing another stimulus only 50% of the time, and by reinforcing a third stimulus 0% of the time (lines 4-7). Using such reinforcement percentages, Wagner, Logan, Haberlandt, and Price (1968) presented the compounds S_1S_2 (always reinforced) and S_2S_3 (never reinforced) and tested for resultant stimulus control of each component of the compound under extinction conditions (line 5). They then compared the relative stimulus control obtained in the 100, 50, and 0% validity case to the relative stimulus control obtained in a case where all three stimuli were only 50% reinforced (line 6). In the former problem, S_1 gained more control than S_2, and both gained more control over responding than S_3. In the latter

Table 2

Three Stimulus Case

	% REINFORCEMENT				STIMULI = # REINFORCED TRIALS/# NONREINFORCED TRIALS										OUTCOME
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1S_2	S_1S_3	S_1S_4	S_2S_3	S_2S_4	S_3S_5	Predicted and/or completed experiments
1.	100	0	0	X	$\frac{33}{00}$	$\frac{00}{33}$	$\frac{00}{33}$	X	X	X	X	X	X	X	Simple discrimination. S_1 gains control.
2.	100	0	0	X	$\frac{50}{00}$	X	X	X	X	X	X	$\frac{00}{50}$	X	X	S_1 should control. Generalization to single stimuli.
3.	100	0	0	X	$\frac{25}{00}$	$\frac{00}{25}$	$\frac{00}{25}$	X	X	X	X	$\frac{00}{25}$	X	X	Little generalization.
4.	100	50	0	X	$\frac{33}{00}$	$\frac{17}{17}$	$\frac{00}{33}$	X	X	X	X	X	X	X	S_1 more than S_2, and both more than S_3.
5.	100	50	0	X	X	X	X	X	$\frac{50}{00}$	X	X	$\frac{00}{50}$	X	X	*Wagner et al. (1968). $S_1 > S_2 > S_3$.
6.	50	50	50	X	X	X	X	X	$\frac{25}{25}$	X	X	$\frac{25}{25}$	X	X	$S_1 = S_2 = S_3$.
7.	100	50	0	X	$\frac{20}{00}$	$\frac{10}{10}$	$\frac{00}{20}$	X	$\frac{20}{00}$	X	X	$\frac{00}{20}$	X	X	$S_1 > S_2 > S_3$.
8.	75	75	50	X	$\frac{25}{08}$	$\frac{25}{08}$	$\frac{16}{16}$	X	X	X	X	X	X	X	$S_1 = S_2$, both should show control over S_3.
9.	75	75	50	X	$\frac{00}{12}$	$\frac{00}{12}$	$\frac{00}{25}$	X	$\frac{25}{00}$	$\frac{12}{00}$	X	$\frac{12}{00}$	X	X	Proposed condition. Condition III. Table 5.

case, S_1, S_2, and S_3 were essentially equal in control of responding.

We can also look at a number of other cases on the continuum of different reinforcement percentages. For example, we may examine the effects of reinforcing compounds more than individual components or vice versa.

The interaction of stimulus modalities with reinforcement percentages may also be observed in the three stimulus case. Presumably, one of the major effects of using different modalities would be to make the task simpler by making the difference between stimuli more perspicuous from the beginning of the experiment.

Four Stimulus Case

Wagner (1969) presented four stimuli in compound equally often, varied reinforcement percentages, and subsequently obtained differential stimulus control. In a correlated condition (line 3, Table 3), the compound S_1S_4 was always reinforced, S_2S_4 always reinforced, and S_3S_4 never reinforced (corresponding to 100, 100, 0, and 66% validity for S_1, S_2, S_3, and S_4). In the uncorrelated condition (line 2), S_1S_4 was always reinforced; S_2S_4, 50% reinforced; and S_3S_4, 50% reinforced (100, 50, 50, and 66% condition). Wagner then compared the amount of control demonstrated by each of the compounds in the two experiments. In the correlated condition, response percentages were higher to S_2S_4 than to S_3S_4 while in the uncorrelated condition, S_2S_4 was equal to S_3S_4.

Wagner's primary concern in the above experiment was to demonstrate how different aggregates of cues can change responding to S_4 even though S_4 receives the same absolute percentage of reinforcement (Responding was higher to S_4 in the correlated condition than in the uncorrelated condition.). Wagner was not, however, interested in the response

Table 3

Four Stimulus Case

	% REINFORCEMENT				STIMULI = # REINFORCED TRIALS/# NONREINFORCED TRIALS										OUTCOME
	S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4	S_1S_2	S_1S_3	S_1S_4	S_2S_3	S_2S_4	S_3S_4	Predicted and/or completed experiments
1.	100	100	0	0	$\frac{25}{00}$	$\frac{25}{00}$	$\frac{00}{25}$	$\frac{00}{25}$	X	X	X	X	X	X	S_1 and S_2 more control than S_3 and S_4.
2.	100	100	0	0	X	X	X	X	$\frac{50}{00}$	X	X	X	X	$\frac{00}{50}$	Possible to solve with 1 cue, but $S_1+S_2 > S_3+S_4$.
3.	100	100	0	66	X	X	X	X	X	X	$\frac{33}{00}$	X	$\frac{33}{00}$	$\frac{00}{33}$	*Wagner (1969) S_2S_4 more control than S_3S_4.
4.	100	50	50	66	X	X	X	X	X	X	$\frac{33}{00}$	X	$\frac{17}{17}$	$\frac{17}{17}$	$S_2S_4 = S_3S_4$.
5.	100	100	50	50	X	X	X	X	$\frac{50}{00}$	X	X	X	X	$\frac{25}{25}$	Possible to solve with only one cue.
6.	75	75	50	0	X	X	X	X	$\frac{25}{00}$	$\frac{12}{00}$	$\frac{00}{12}$	$\frac{12}{00}$	$\frac{00}{12}$	$\frac{00}{25}$	Proposed condition. Condition I. Table 4.
7.	75	75	25	0	X	X	X	X	$\frac{37}{00}$	$\frac{06}{00}$	$\frac{00}{06}$	$\frac{06}{00}$	$\frac{00}{06}$	$\frac{00}{37}$	Proposed condition. Condition II. Table 4.
8.	75	50	25	0	$\frac{18}{03}$	$\frac{12}{12}$	$\frac{03}{18}$	$\frac{00}{25}$	X	X	X	X	X	X	$S_1 > S_2 > S_3 > S_4$.
9.	66	33	33	0	X	X	X	X	$\frac{16}{00}$	$\frac{16}{00}$	$\frac{00}{16}$	$\frac{00}{16}$	$\frac{00}{16}$	$\frac{00}{16}$	S_1 more control than the other three.

percentages to all the other stimuli when presented alone. The question may be asked whether Wagner would have obtained different amounts of stimulus control related to the different percentages of reinforcement if he had tested each individual stimulus. Certainly it seems that if an animal could distinguish different reinforcement percentages, then he could demonstrate this discrimination between individual stimuli even though these stimuli were always presented in compound and never presented alone.

A common assumption of many theories of discrimination learning (Bush & Mosteller, 1951; Estes & Burke, 1953; Hull, 1943; Rescorla & Wagner, 1972; Spence, 1936) is that reinforcement increases the associative tendency between itself and a preceding stimulus toward some asymptotic value, and nonreinforcement decreases the associative tendency. And although various theories prefer different terminology, each theory seems to agree that increments due to reinforcement and decrements due to nonreinforcement are negatively accelerated functions; that is, as each stimulus comes to predict reinforcement with greater certainty, the amount that it can be increased decreases.

Different amounts of stimulus control may be obtained by single stimuli because each stimulus may have a different asymptote for different percentages of reinforcement. For example, a 100% reinforced stimulus may have a higher asymptotic level than a 50% reinforced stimulus.

In dealing with compound stimuli, the above theories seem to disagree. On the one hand (Bush & Mosteller, Estes & Burke, Hull, and Spence), is the assumption that the associative strength of each component of the compound is modified until the component itself reaches its own asymptote. On the other hand (Wagner & Rescorla), is the assumption that the associative value of each component changes only until the "collective value of the compound" reaches asymptote.

Thus, we have two predictions for the experimental question. One prediction, based on the premise that each component reaches its own asymptote, suggests that an organism should be able to distinguish different reinforcement percentages even though these stimuli always appear in compound and never alone. The other prediction (Wagner & Rescorla) suggests that whether or not an organism makes the discrimination between different reinforcement percentages depends upon the aggregate associative strength of the compounds themselves in predicting reinforcement. The associative value of the individual components of a compound cannot be incremented or decremented further once the compound has reached its asymptotic level.

Experimentation

The present experiment was designed initially to see if organisms could distinguish between different reinforcement percentages of different stimuli, even though these stimuli always appear in compound and never in isolation. Results of the first two conditions in which four stimuli were always presented in compound indicated that an examination of these same reinforcement percentages needed to be studied under conditions where only two or three stimuli were presented.

Tables 4 and 5 summarize the conditions which were imposed during the present experiment. These tables have a similar format to Tables 1, 2, and 3. Column 1 labels the condition. Under Column 2, the number of subjects used in each condition is listed. Column 3 represents the reinforcement percentages of each stimulus. The reinforcement

Table 4

Summary of Conditions Using Four Stimuli in Two Different Modalities

CONDITIONS	N	% REINFORCEMENT				STIMULI = # REINFORCED TRIALS/# NONREINFORCED TRIALS									
		T_1	T_2	T_3	L	T_1	T_2	T_3	L	T_1T_2	T_1T_3	T_2T_3	T_1L	T_2L	T_3L
Ia	4	75	75	50	0	X	X	X	X	$\frac{26}{00}$	$\frac{13}{00}$	$\frac{13}{00}$	$\frac{00}{13}$	$\frac{00}{13}$	$\frac{00}{26}$
Ib	4	75	50	75	0	X	X	X	X	$\frac{13}{00}$	$\frac{26}{00}$	$\frac{13}{00}$	$\frac{00}{13}$	$\frac{00}{26}$	$\frac{00}{13}$
Ic	4	50	75	75	0	X	X	X	X	$\frac{13}{00}$	$\frac{13}{00}$	$\frac{26}{00}$	$\frac{00}{26}$	$\frac{00}{13}$	$\frac{00}{13}$
IIa	4	75	75	25	0	X	X	X	X	$\frac{37}{00}$	$\frac{06}{00}$	$\frac{06}{00}$	$\frac{00}{06}$	$\frac{00}{06}$	$\frac{00}{37}$
IIb	4	75	25	75	0	X	X	X	X	$\frac{06}{00}$	$\frac{37}{00}$	$\frac{06}{00}$	$\frac{00}{06}$	$\frac{00}{37}$	$\frac{00}{06}$
IIc	4	25	75	75	0	X	X	X	X	$\frac{06}{00}$	$\frac{06}{00}$	$\frac{37}{00}$	$\frac{00}{37}$	$\frac{00}{06}$	$\frac{00}{06}$

Table 5

Summary of Conditions Using only Two or Three Stimuli in the Same Modality

CONDITIONS	N	% REINFORCEMENT				STIMULI = # REINFORCED TRIALS/# NONREINFORCED TRIALS									
		T_1	T_2	T_3	L	T_1	T_2	T_3	L	T_1T_2	T_1T_3	T_2T_3	T_1L	T_2L	T_3L
IIIa	4	75	75	50	-	$\frac{00}{13}$	$\frac{00}{13}$	$\frac{00}{26}$	X	$\frac{26}{00}$	$\frac{13}{00}$	$\frac{13}{00}$	X	X	X
IIIb	4	75	50	75	-	$\frac{00}{13}$	$\frac{00}{26}$	$\frac{00}{13}$	X	$\frac{13}{00}$	$\frac{26}{00}$	$\frac{13}{00}$	X	X	X
IIIc	4	50	75	75	-	$\frac{00}{26}$	$\frac{00}{13}$	$\frac{00}{13}$	X	$\frac{13}{00}$	$\frac{13}{00}$	$\frac{26}{00}$	X	X	X
IVa	2	75	50	-	-	$\frac{00}{16}$	$\frac{00}{42}$	X	X	$\frac{42}{00}$	X	X	X	X	X
IVb	2	50	75	-	-	$\frac{00}{42}$	$\frac{00}{16}$	X	X	$\frac{42}{00}$	X	X	X	X	X
IVc	2	75	-	50	-	$\frac{00}{16}$	X	$\frac{00}{42}$	X	X	$\frac{42}{00}$	X	X	X	X
IVd	2	50	-	75	-	$\frac{00}{42}$	X	$\frac{00}{16}$	X	X	$\frac{42}{00}$	X	X	X	X
IVe	2	-	75	50	-	X	$\frac{00}{16}$	$\frac{00}{42}$	X	X	X	$\frac{42}{00}$	X	X	X
IVf	2	-	50	75	-	X	$\frac{00}{42}$	$\frac{00}{16}$	X	X	X	$\frac{42}{00}$	X	X	X
Va	4	50	-	-	75	$\frac{00}{42}$	X	X	$\frac{00}{16}$	X	X	X	$\frac{42}{00}$	X	X
Vb	4	75	-	-	50	$\frac{00}{16}$	X	X	$\frac{00}{42}$	X	X	X	$\frac{42}{00}$	X	X

percentages are obtained by calculating the number of times a stimulus has been presented and reinforced (or presented and nonreinforced). Under Column 4, the actual number of stimulus presentations for the various conditions is listed. The presentation of a stimulus is represented as the number of reinforced trials over the number of nonreinforced trials. S_1, S_2, S_3, and S_4 of Tables 1-3 have been replaced by Tone one (T_1), Tone two (T_2), Tone three (T_3), and a light (L).

Conditions Ia, Ib, and Ic represent three counterbalanced groups in which stimuli always appeared in compound and never alone. Reinforcement percentages were 75, 75, 50, and 0, as listed. T_1 was a tone of 220 Hz., T_2 was 1700 Hz., and T_3 was 8000 Hz. The light was the 0% reinforced stimulus.

Conditions IIa, IIb, and IIc were counterbalanced groups in which reinforcement percentages were changed, and the frequencies of T_1 and T_2 were changed to 1900 Hz. and 3000 Hz. respectively. Again, stimuli were in two different modalities.

Conditions IIIa, IIIb, and IIIc show a change from four stimuli to three stimuli. The reinforcement percentages were the same as those of Condition I, but stimuli here were in the same modality.

Conditions IV and V represent counterbalanced groups with only two stimuli presented to the animals. However, Condition IV differs from Condition V in that stimuli of Condition IV are in the same modality while stimuli of Condition V are in two modalities.

METHOD

Subjects. The number of subjects used in each condition is summarized in column 2 in Tables 4 and 5. The rats were from the animal colony at the University of New Mexico. They were taken down to and maintained at 80% ad lib body weight throughout the experiment. All rats were approximately 120 days old at the start of the experiment. The rats of Condition I were male hooded rats while female albino rats were used in Conditions II through V.

Apparatus. The same apparatus was used in all five conditions. The apparatus consisted of four modified Skinner boxes of varying sizes, each equipped with a feeder, a house light, and a speaker. The boxes were constructed with plexiglass except for the grid floors. Each box was placed in an ice chest, which was converted for the purpose of isolating the animals from surrounding noises and lights. In addition, masking noise was provided by small fans attached to each box. It must be noted that, although the boxes were not identical, the variation in size was not a critical factor since the rats were trained and tested in the same box throughout the experiment.

Stimulus presentations were punched on a tape and read by an eight-track Friden tape reader. Four stimuli were capable of being presented. These stimuli included three tones and a light. The tones were provided by three separate tone generators, and the house light was used as a light stimulus.

Each box was enabled for three seconds before any stimulus was presented. If, at any time during this prestimulus interval, a response was made, the stepper advanced the impulse and enabled the next box. The animal was, therefore, penalized for responding too early by missing a stimulus presentation. If no response was made during the three second prestimulus interval, the stimuli, as dictated by the tape, were presented. Unless a response terminated the presentation, the stimuli stayed on for a duration of three seconds. Responses were counted in both the prestimulus interval and during the trial itself. The number of reinforcements (45 mg. Noyes food pellets) earned by each animal was also recorded.

Procedure. All animals were randomly divided into groups and began bar press training in the apparatus after approximately 48 hours of food deprivation. A CRF schedule was maintained for two training days, and each animal was left in the apparatus until 100 reinforcements had been attained each day.

All three tones had been equated for intensity by a sound intensity meter. Initially, the tones were selected so that they were easily distinguishable and separable when occurring in compounds (as heard by the experimenter).

All groups were presented with semi-random sequences of stimuli (Each compound or single stimuli during training could occur no more than three times in succession.). If a separate test phase was needed (those cases in which each stimulus did not appear alone at some time), each stimulus was inserted semi-randomly in blocks of four into the original sequence of stimulus presentations. The stipulation was that the first 15 trials never contained any test stimuli to allow for any warm-up effect.

Training continued until the rat approached a high asymptote of correct responding (number of reinforced responses divided by the number of all responses made during the stimulus presentations). A second calculation was made to ensure that rats were responding primarily during stimulus presentations. The number of responses during stimulus presentation was divided by the total number of responses. Both measurements were required to reach asymptote before testing began.

During testing, responses to each stimulus alone were tabulated by hand. In assessing stimulus control, the number of responses to each stimulus was then divided by the total number of times it had been presented. Testing continued for three days and terminated when no change over days was noted.

RESULTS

Conditions Ia, Ib, and Ic. Acquisition data of response percentages to tone-tone and tone-light compounds are shown in Figure 1. Response percentages (top graph) increased over days to tone-tone compounds and decreased over days to the tone-light compounds. The bottom graph in Figure 1 shows that the percent correct responding (the number of reinforced responses divided by total responses to all stimuli) and percent responding done only during the interval of stimulus presentation both increased over days.

A 3 X 3 X 2 factor analysis of variance (tones X days X presence or absence of the light (0% reinforced)) was used to test the results. The analysis verifies that response percentages to the stimuli did not change over testing days, and no significant group difference was obtained. However, the analysis of variance demonstrated a higher percentage of responding to the higher pitched tones for all three groups ($\underline{F}$ (1,10) = 11.197, $\underline{p} < .01$).

However, the most dramatic result of the experiment was the effect of the light as a controlling stimulus. Low response percentages were obtained to the light when presented alone, high response percentages were obtained to the tones alone, and intermediate response percentages were obtained to the tone-light compounds; in other words, the light had become a conditioned inhibitor. The 0% reinforcement effect (the light) caused large differences in percent responding as demonstrated by an $\underline{F}$-test ($\underline{F}$ (1,10) = 145.40, $\underline{p} < .01$).

In Figure 2 the data for all animals in Conditions Ia, Ib, and Ic were averaged for responding to all stimuli across testing days. The top bar graph in Figure 2 shows the results of Condition Ia. T_1 showed

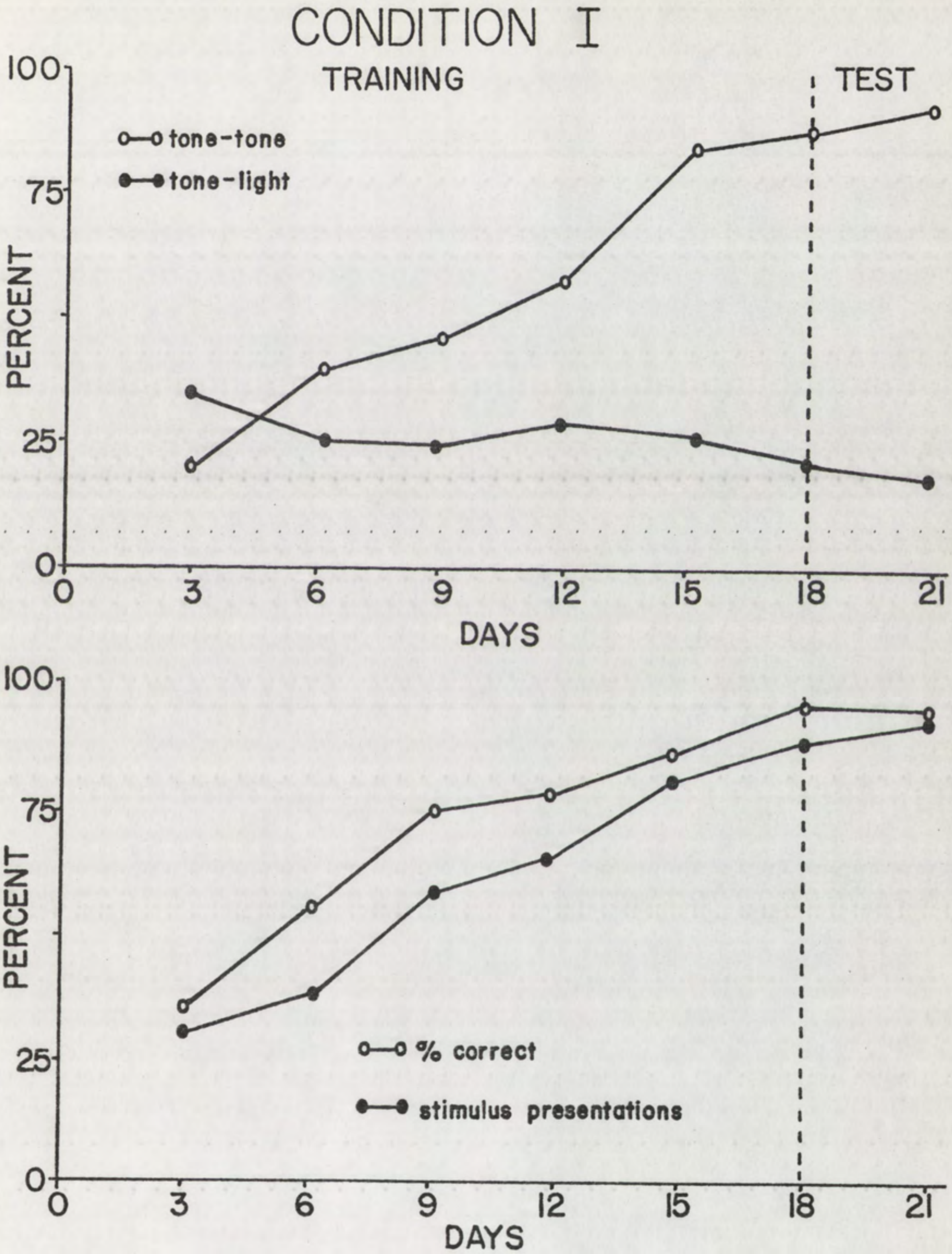

Fig. 1. Percent responding to tone-tone and tone-light compounds (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

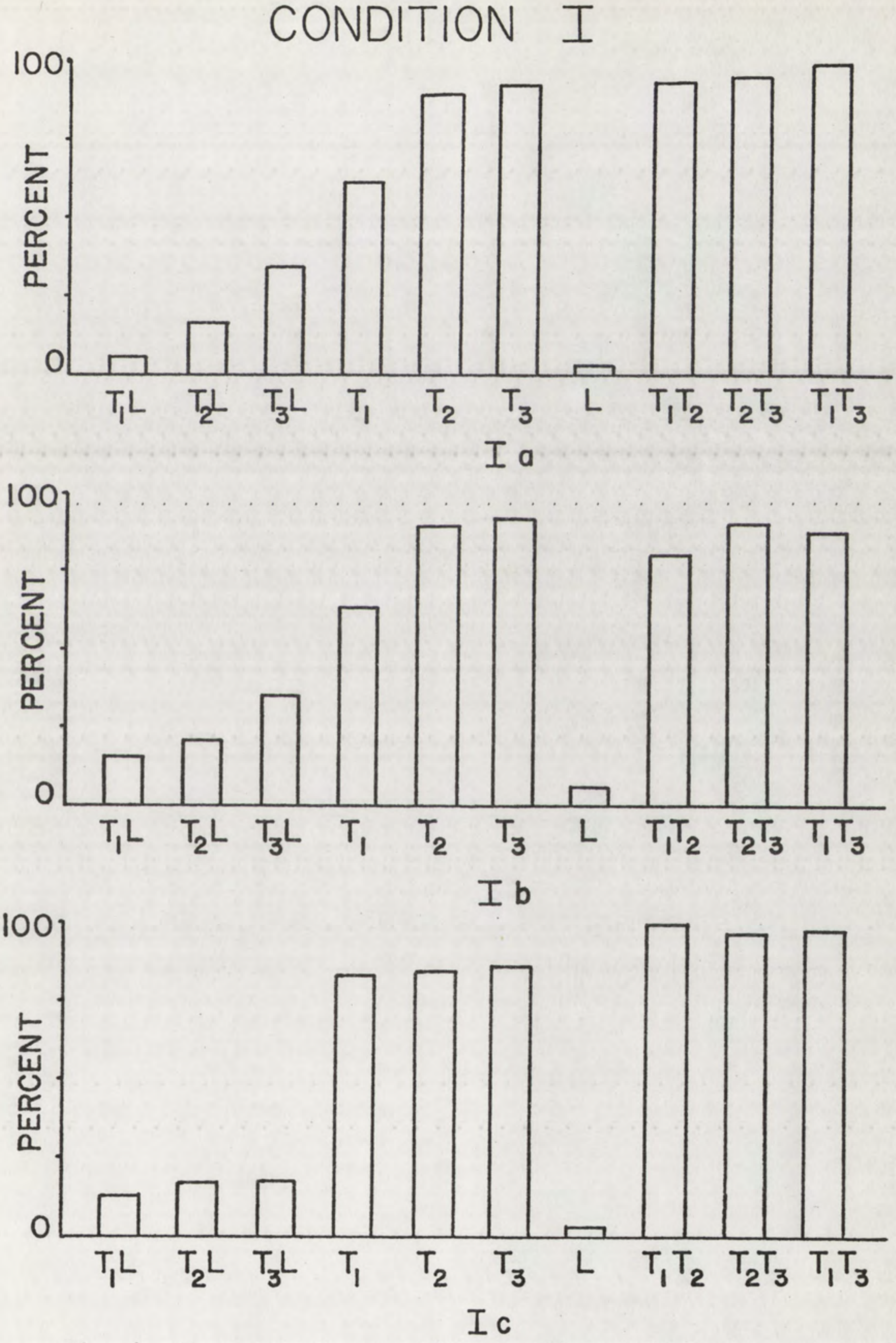

Fig. 2. Mean percent responding to all stimuli during testing in Conditions Ia (top), Ib (middle), and Ic (bottom).

the lowest percent responding compared to T_2 and T_3 since T_1 was reinforced only 50% of the time while T_2 and T_3 were reinforced 75% of the time. However, T_2 should have been lower in response percentage than T_1 or T_3 in Condition Ib (second bar graph), but it was not lower. Similarly, T_3 should have been lower than T_1 or T_2 in Condition Ic (bottom bar graph), but it was not.

Compare the low response percentages to the light alone in all three graphs to the high response percentages of the three tones when presented alone. The effect of the light as a conditioned inhibitor is evident. The light with a low response percentage decreased the tendency to respond to the tones when the two were in compound with each other. All tone-light compounds showed intermediate response percentages between the tones alone and the light alone.

Differential responding due to different reinforcement percentages between the 75% and the 50% reinforced cues was not obtained. Response percentages showed a response bias toward the higher tones (T_2 and T_3) in all three groups.

Conditions IIa, IIb, and IIc. Table 4 shows that, in Conditions IIa, IIb, and IIc, the percentage of reinforcement was changed from 75, 75, 50, 0 to 75, 75, 25, 0 because no difference was obtained between 75% and 50% cues in Condition I. Secondly, because in Condition I results demonstrated a preference by the rats for higher pitched tones, T_1 and T_2 were changed from 220 Hz. and 1900 Hz. to 1700 Hz. and 3000 Hz.

Acquisition data were similar to those of Condition I. Response percentages to the tone-tone compounds increased over days while response percentages to the tone-light compounds decreased over days. Figure 3 shows the acquisition data to tone-tone and tone-light

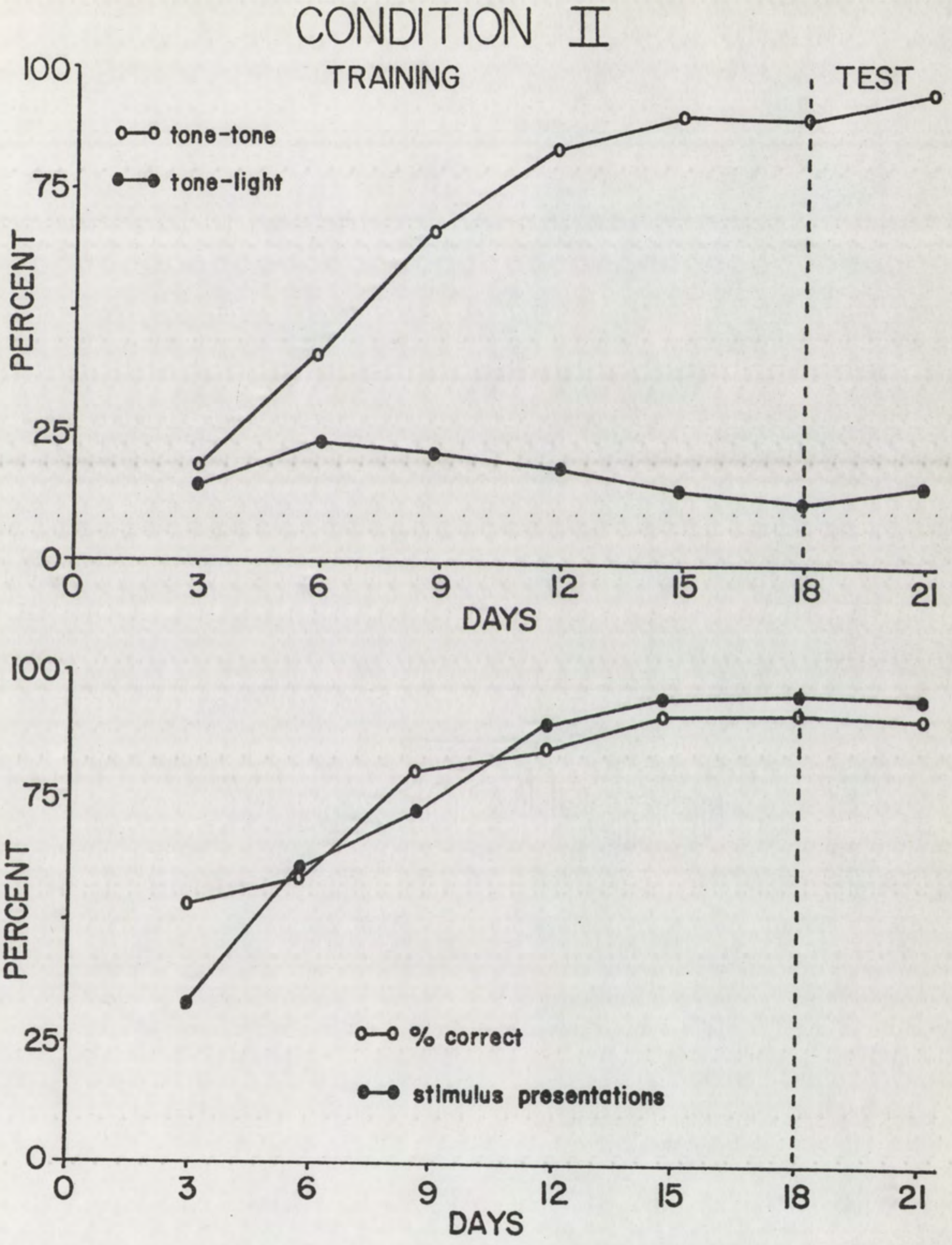

Fig. 3. Percent responding to tone-tone and tone-light compounds (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

compounds. Shown also are the percent correct responding and the percent responding done only during the stimulus presentation. Both increased over days (bottom graph).

Again, the light demonstrated itself to be a strong controlling stimulus as a conditioned inhibitor. Response percentages to the light alone were near zero while response percentages to the tones, presented alone, were high. The presentation of tone-light compounds resulted in intermediate response percentages.

A within-subjects 2 X 3 (reinforcement percentage (75 versus 25) X Condition) analysis of variance demonstrated a significant difference in responding due to the reinforcement manipulation. The percentage of responses emitted to the 75% reinforced cues, regardless of which condition, proved to be consistently higher than the percentage of responses emitted to the 25% reinforced cues ($\underline{F}$ (1,9) = 6.33, $\underline{p} < .05$). There was no significant difference between conditions as demonstrated by the nonsignificant $\underline{F}$-ratio ($\underline{F}$ (2,9) = .410), nor was there any difference due to an interaction effect between conditions and reinforcement percentages ($\underline{F}$ (2,9) = 1.166).

The response percentages to all stimuli across testing days for all animals in each condition were averaged. Results are graphically displayed in Figure 4. In the top bar graph, T_1 was the 25% reinforced cue, and subsequently, T_1 was lower in response percentage than both T_2 and T_3. In Condition IIb (second bar graph), T_2 was lower than T_1 and T_3 since T_2 was 25% reinforced while T_1 and T_3 were 75% reinforced. In the third counterbalanced group (bottom bar graph), T_3 was lower than T_1 and T_2. Thus, the prediction of differential stimulus control due to different reinforcement percentages was upheld for all three conditions.

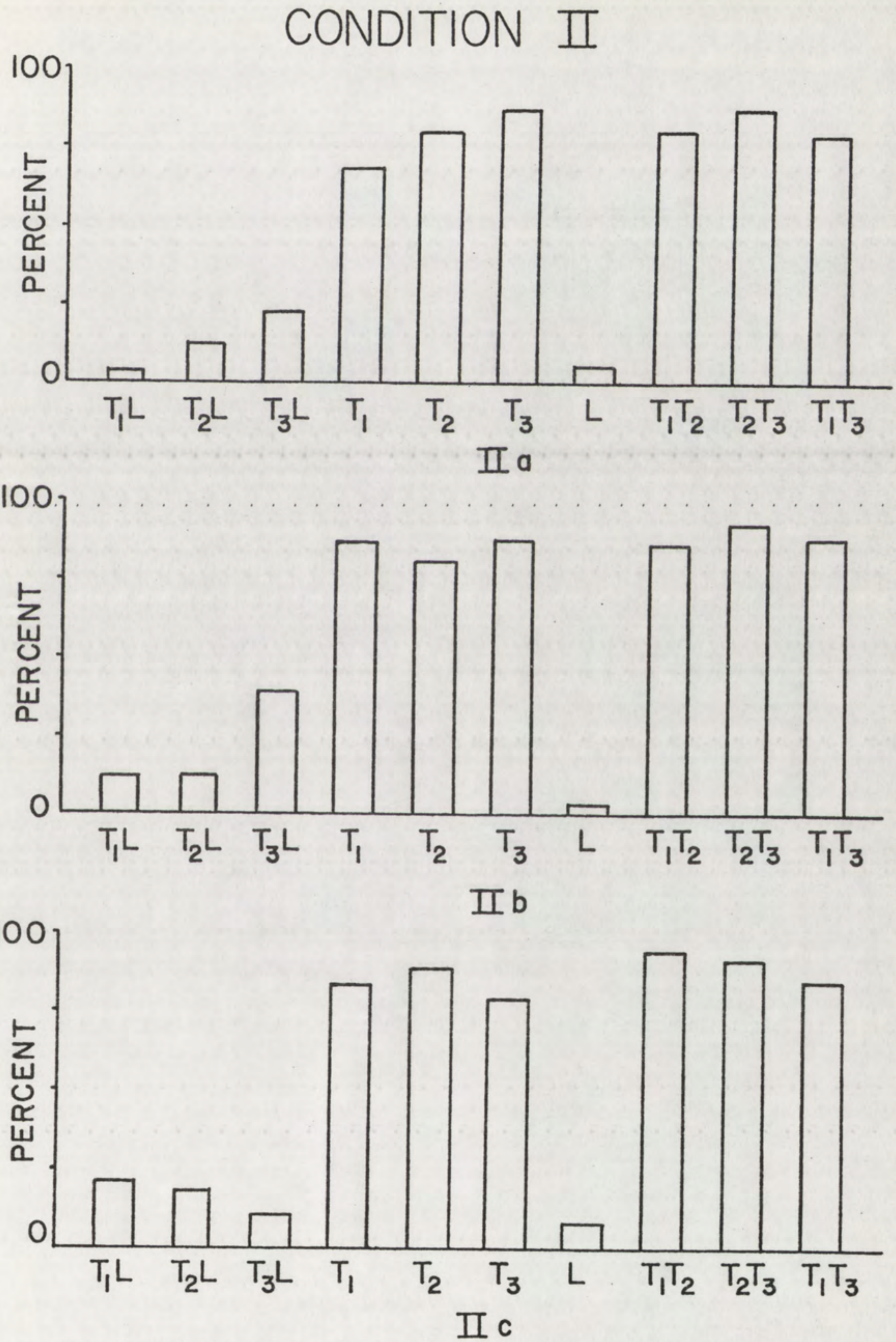

Fig. 4. Mean percent responding to all stimuli during testing in Conditions IIa (top), IIb (middle), and IIc (bottom).

The bar graphs also show more clearly the effect of the light as a conditioned inhibitor. The light alone showed a low response percentage in all three conditions compared to high response percentages to the tones alone. The tone-light compounds showed that percent responding to the tones was greatly reduced when the tones were compounded with the light. Notice also in Figure 4 that not only was there differential responding to the tones alone, but also that there was differential responding to the tone-light compounds. T_1L in Condition IIa (top bar graph) was lower than T_2L and T_3L. In IIb, T_2L was lower than T_3L and T_1L, and T_3L was lower than T_1L and T_2L in IIc.

The prediction of differential stimulus control due to different reinforcement percentages was supported in Condition II. Secondly, Condition II replicated the effect of the light as a conditioned inhibitor as demonstrated in Condition I.

Conditions IIIa, IIIb, and IIIc. Table 5 shows that the number of stimuli was decreased from four to three in Condition III. Results from Conditions I and II indicated that the light stimulus had a strong controlling effect. Perhaps this controlling effect was most effective in the situation where the discrimination was the most difficult; i.e., in Condition I where the difference to be discriminated was between 75 and 50% rather than 75 and 25% of Condition II. The remaining conditions were designed to assess any difference in responding between 75% and 50% reinforced stimuli. The pitches of the tones were left at the same frequency as in Condition II.

Acquisition data for Condition III were considerably different from those of previous conditions. The top graph of Figure 5 shows that percent responding to the tone-tone compounds increased across

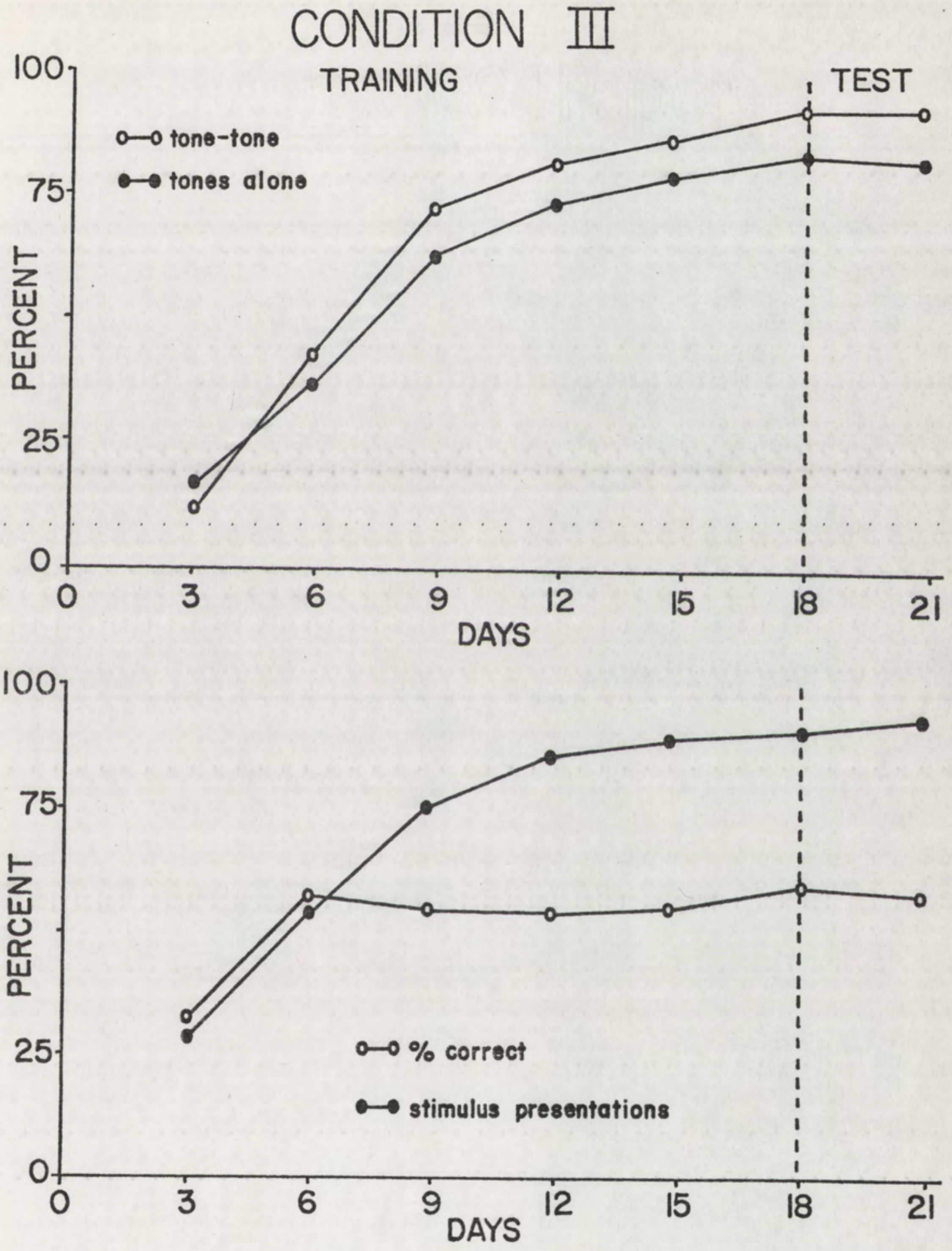

Fig. 5. Percent responding to tone-tone compounds and to tones presented alone (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

days, and percent responding to the tones alone also increased over days (although any stimulus in isolation was never reinforced). Percent responding to the tones alone was lower than for tone-tone compounds. More significantly, as shown in the bottom graph of Figure 5, the animals never reached the high asymptotic levels as in Conditions I and II in percent correct responding. In essence, the animals never solved the discrimination to 80 or 90% accuracy as was the case in the previous conditions. Percent correct responding never reached 60%. The percentage of times the animals responded only during stimulus presentations did show the usual negatively accelerated curve found in the other experiments.

Results indicated a difference in response percentages between the 75% reinforced cues and the 50% reinforced cue. This difference between the 50% reinforced cue and the 75% reinforced was statistically significant ($\underline{F}$ (1,9) = 10.455, $\underline{p} < .01$). In this experiment, there was no group effect ($\underline{F}$ (2,9) = .380), nor was there any group by treatment interaction effect ($\underline{F}$ (2,9) = .0454).

The data are graphically displayed in Figure 6. The top graph of Figure 6 shows that T_1, the 50% reinforced cue, was lower in percent responding than both T_2 and T_3, both 75% reinforced cues. In Condition IIIb, T_2 was lower than T_1 or T_3, and in Condition IIIc, T_3 was lower than T_1 or T_2.

Even though the animals did not reach a high asymptote of correct responding, a difference between 50% and 75% reinforced cues was observed. The removal of the light as a stimulus appeared sufficient to allow a difference between 75% and 50% reinforcement to be demonstrated.

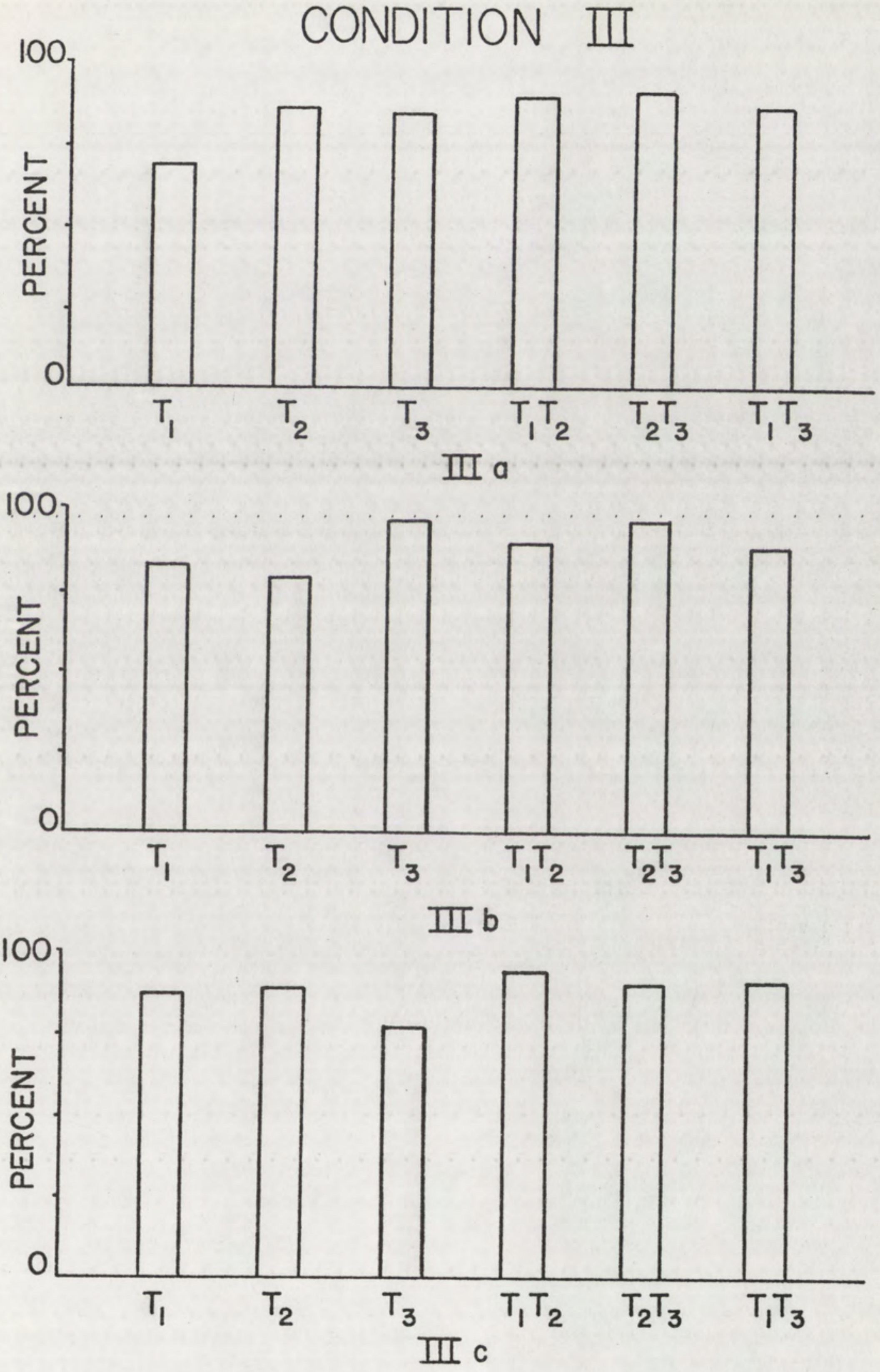

Fig. 6. Mean percent responding to all stimuli during testing in Conditions IIIa (top), IIIb (middle), and IIIc (bottom).

Conditions IVa, IVb, IVc, IVd, IVe, and IVf. The low asymptotic level of percent correct responding in Condition III indicated that the task of distinguishing between stimuli in the same modality with reinforcement percentages of 75, 75, and 50 was difficult. Condition IV subjected animals to a discrimination between only two stimuli with 75 and 50 reinforcement percentages. Perhaps, larger differences could be obtained if the problem were simplified.

Acquisition data are shown in Figure 7. Both percent responding to tone-tone compounds and tones alone increased over days as in Condition III. Although the percentage of responding to the tone-tone compounds was above the percentage of responding to the tones alone, the closeness of the two acquisition curves again indicated that the task was difficult and the discrimination poor. The bottom graph also shows that the discrimination was poorly obtained. The percentage of correct responding approached only 50% while the percentage of responding done only during the stimulus presentations increased over days and reached a high asymptote.

The same analysis of variance for Condition III was performed on the data of Condition IV. The analysis of variance demonstrated that there was no group effect (F (5,6) = 3.864) nor reinforcement percentage effect (F (1,6) = 2.571). There was, however, a group by reinforcement interaction effect (F (5,6) = 8.095, $p < .05$). These three F-tests indicated that the discrimination was a difficult one, and that if the discrimination were obtained at all, it depended on which group, or more importantly, which tones were presented with what reinforcement percentage.

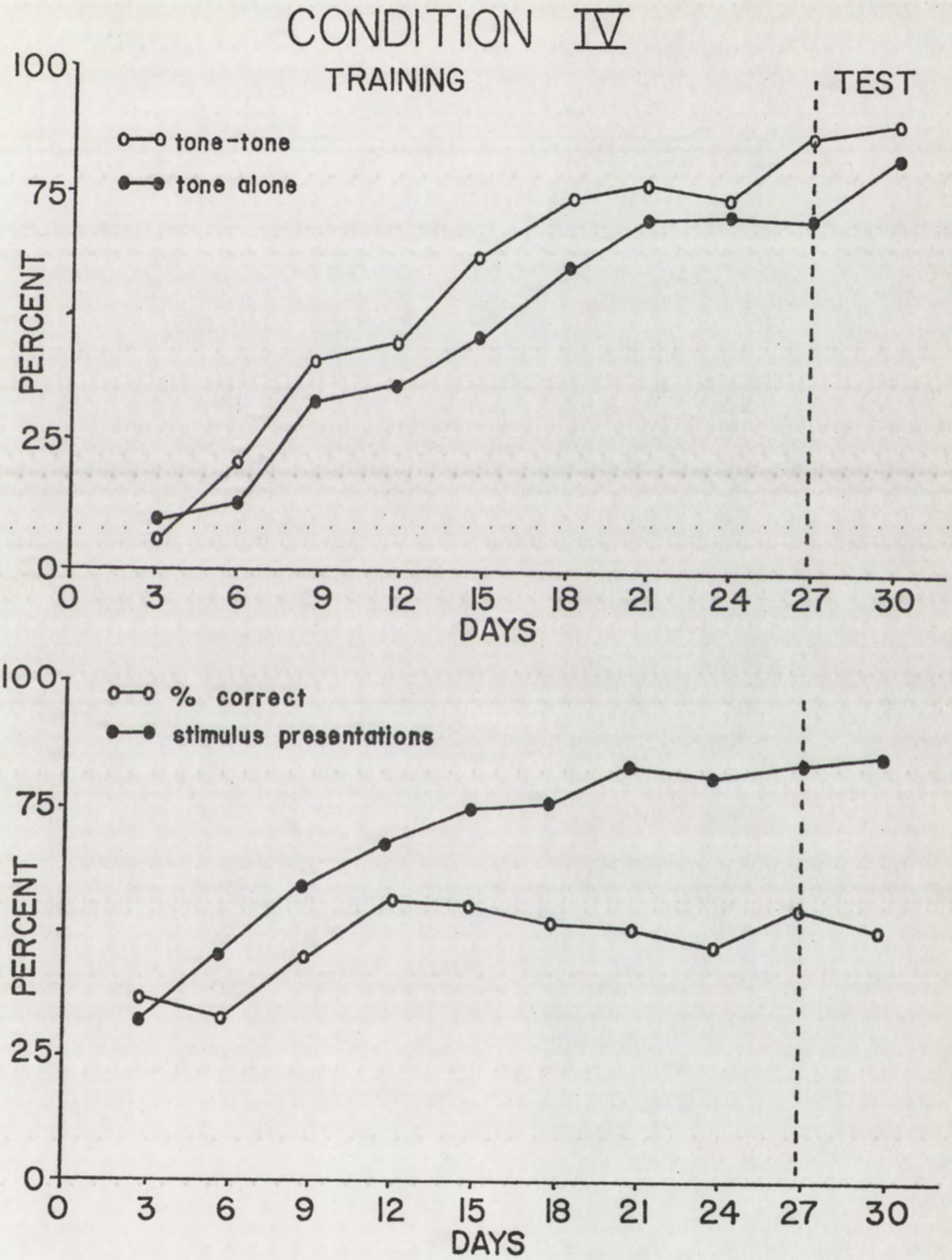

Fig. 7. Percent responding to tone-tone compounds and to tones presented alone (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

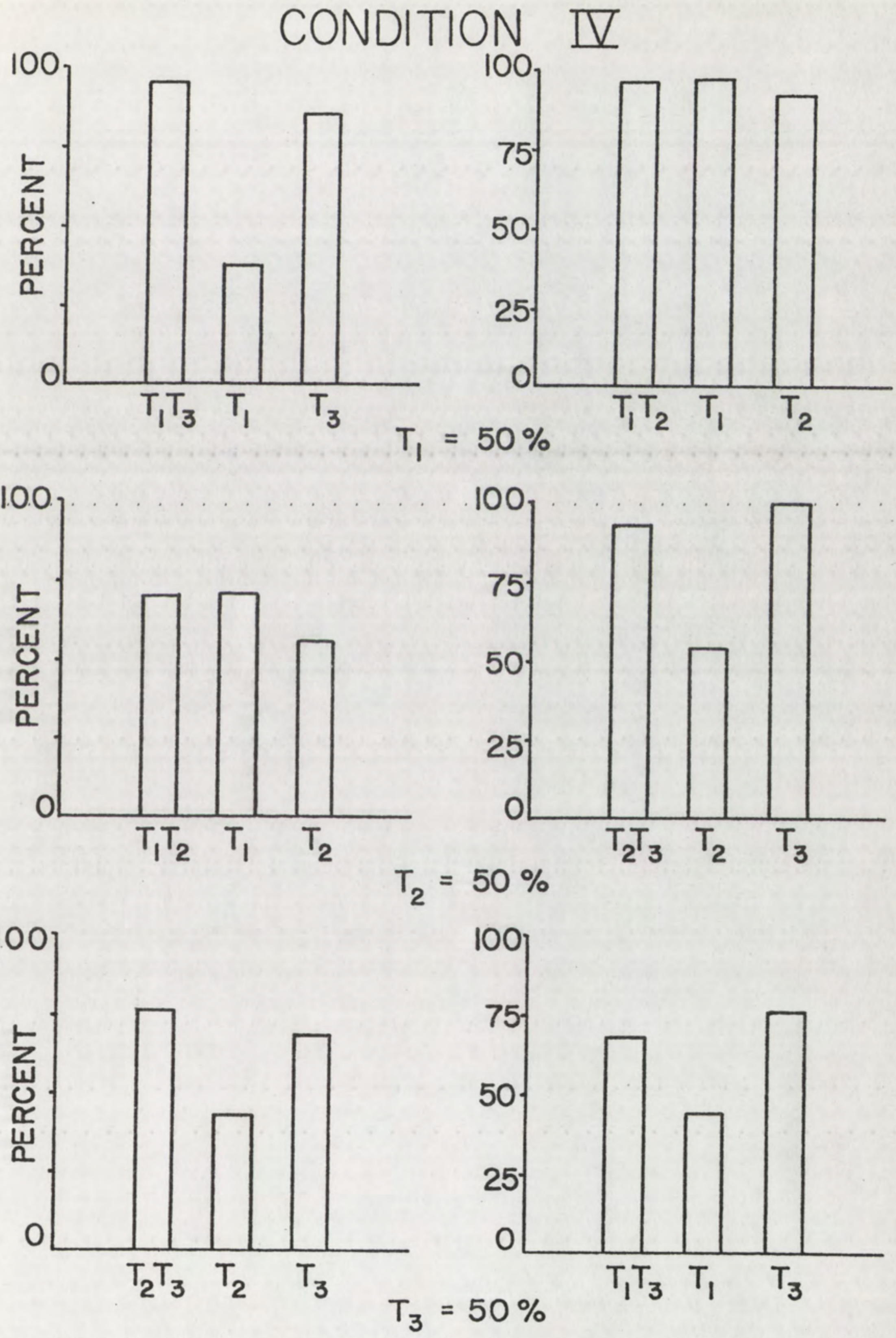

Fig. 8. Mean percent responding to all stimuli during testing in Conditions IVa (top left), IVb (top right), IVc (middle left), IVd (middle right), IVe (bottom left), and IVf (bottom right).

These results are shown graphically in Figure 8. If the discrimination to be made was between T_1 and T_2 (Conditions IVb and IVc), the difference in response percentages was small. The largest differences in response percentages were obtained in Conditions IVa and IVf where the discrimination to be made was between T_1 and T_3. The difference between T_2 and T_3 (Conditions IVd and IVe) was also easier than the discrimination between T_1 and T_2.

Conditions Va and Vb. Condition IV indicated that the difference between a 75% and 50% reinforced cue depended upon how far apart the tones were psychophysically. The confounding produced by different cue saliencies suggested that the difference between 75% and 50% reinforced cues might be better studied with two highly discriminable, salient cues. Condition V used the light and T_3 as stimuli since both had been previously demonstrated as highly salient cues.

The two graphs of Figure 9 display the acquisition curves for Condition V. The top graph shows that response percentages to the tone-light compound increased over days, but the response percentages to the tone or light alone decreased over days. The top graph also shows that this task appeared to be relatively easy as demonstrated by the large difference between the two curves. The bottom graph shows that both the percent correct responding and percent responding only during stimulus presentation increased over days. Both curves reached a high asymptotic level unlike those of Condition IV.

Analysis of variance indicated that there was no group effect as shown by F-test (F (1,6) = 1.857), but there was a significant difference between the 75 and 50% reinforced cues (F (1,6) = 15.385, $p < .01$).

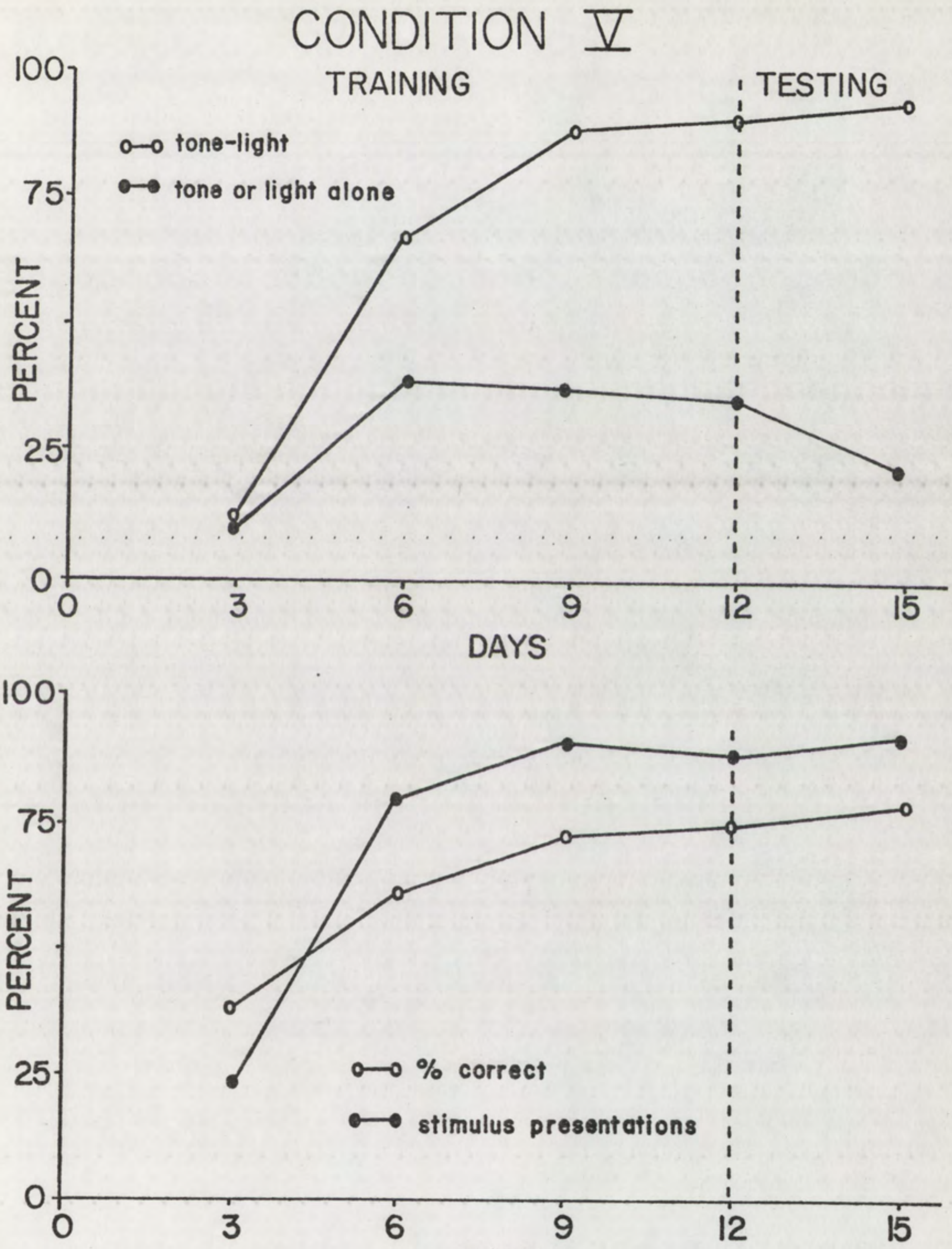

Fig. 9. Percent responding to tone-light compounds and responding to either the tone alone or light alone (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

There also was no group by reinforcement interaction effect (F (1,6) = 2.308).

The significant differences are shown in Figure 10. The top graph shows that T_3 (75% reinforced) had a higher average percentage of responding than L (50% reinforced) in Condition Va. The bottom graph shows that L (75%) had a higher average percentage of responding than T_3 (50%).

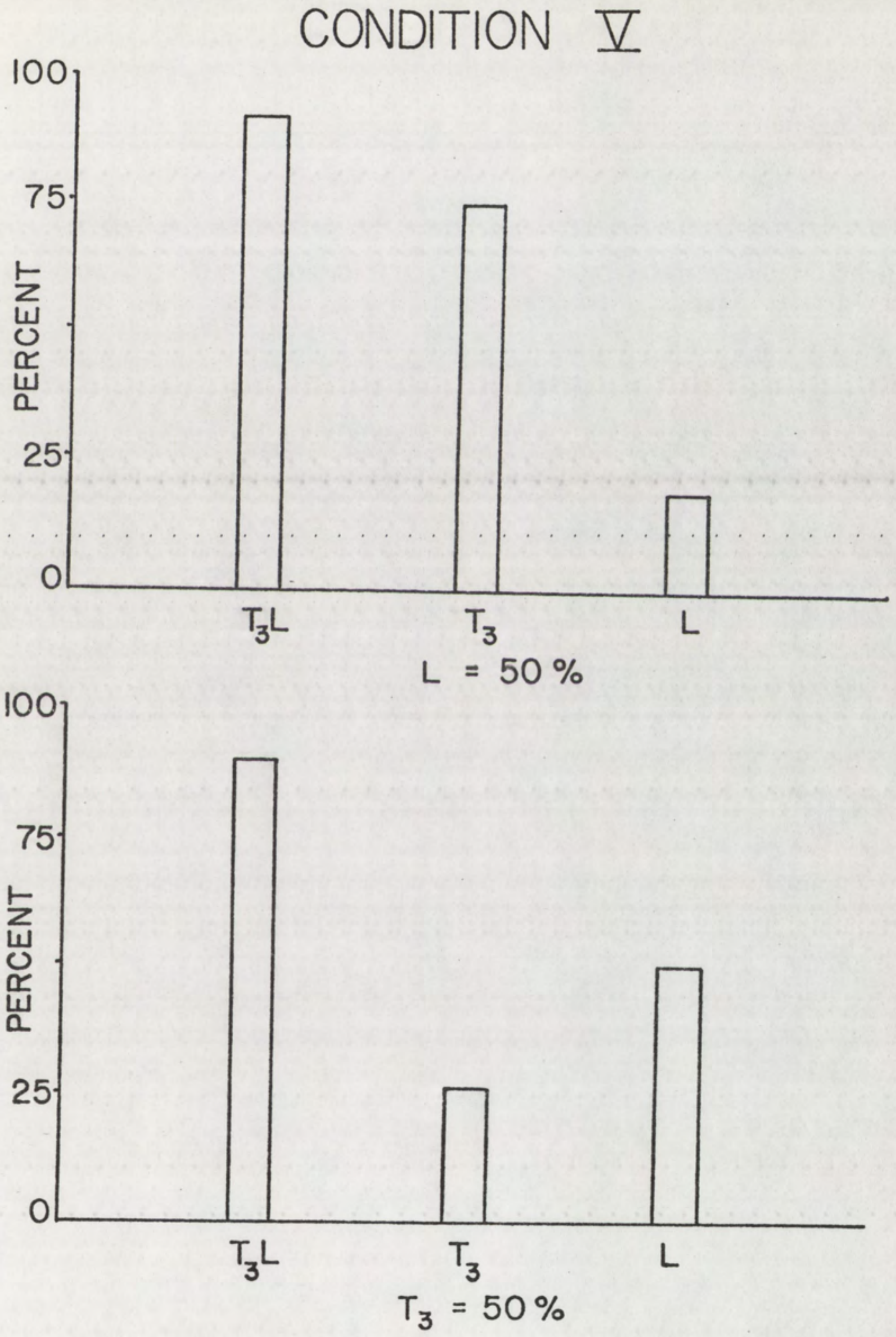

Fig. 10. Mean percent responding to all stimuli during testing in Conditions Va (top) and Vb (bottom).

DISCUSSION

Although the domain from which this sample of conditions was drawn is enormous, the results lend credence to the view of cue relevance as a continuum. That is to say, stimulus control over responding or not responding depends on both the absolute and relative information value of a cue vis-a-vis emotionally significant events. Specifically, it was shown that a cue can gain conditioned inhibitory properties in the context of appetitive instrumental conditioning by signalling nonreinforcement, and that cues that are imperfect predictors of reinforcement gain conditioned excitatory properties in accord with their programmed validities. However, these generalizations must be tempered by further consideration of the number of stimulus modalities involved, their perspicuities and similarities.

Examination of the effect of the light as a conditioned inhibitor indicated that the light was a highly informative cue. As a consistent predictor of nonreinforcement (at one end of the continuum of cue relevance), the light gained control over responding, or more appropriately, gained control over the response of "not responding." However, the information value of the tones was considerably less than the information which could be provided by perfect predictors of reinforcement or nonreinforcement. In analyzing the tones for their information value, results indicated a complex interaction between reinforcement percentages and the psychophysical properties of the tones. When the difference between tones was 75% and 25%, differential responding in accord with viewing stimulus control along a continuum was obtained. However, when the difference between stimuli was 75% and 50%, differential responding was obtained only in those cases where stimuli were farther apart psychophysically. Specifically, large differences were found when the tones were more distinguishable from each other. T_1 and T_3 showed the largest differences in percent responding, followed by T_2 and T_3, and the smallest differences were found between T_1 and T_2 (also closest together in frequency). Even larger differences were obtained when stimuli were in different modalities (Condition V).

In comparing the validities of single stimuli to compound stimuli, both absolute and relative information values may again be assessed. Reduced responding to any tone alone reflected the absolute information value of the tones as inconsistent predictors of reinforcement or nonreinforcement. High levels of responding to the tone-tone compounds were in agreement with the fact that the compounds themselves were perfect predictors of reinforcement (100% reinforced). In this case, the information value of the tone-tone compounds was greater than the information value of any tone in isolation.

The tone-light compounds, on the other hand, were equally as informative in predicting nonreinforcement as the light by itself. Furthermore, responding to the tone-light compounds indicated another important aspect of compound stimuli. A compound may not only be responded to as if it were a single stimulus with one bit of information, but also a compound may demonstrate the tendency of an organism to respond to the components of a compound as supplying different bits of information (Conditions I and II).

In conclusion, this experiment has shown an example of compounds which are more informative than their components in predicting emotionally significant events, and it has shown that both components of a compound may contribute individually to responding. These two results seem to indicate that compounds cannot be viewed in any simple manner. In some situations, a compound may be more informative than its individual components, and in these cases, small differences in responding would be expected between components themselves. In other situations where single stimuli are easily discriminable both psychophysically and through differences in reinforcement percentages, individual components of a compound may reach different asymptotic levels.

A workable theory of discrimination learning must account for differences not only between stimuli themselves but also between compounds and their components. An account should be made for the selection of stimuli which prove to be the most functional in predicting the occurrence (or nonoccurrence) of emotionally significant events. However, the functional importance of a stimulus depends not only upon its absolute value in predicting reinforcement, but also upon the validities of other stimuli, both isolated and compounded, and their physical differences.

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APPENDICES

APPENDIX I

REVIEW OF THE LITERATURE

There were several underlying issues surrounding the continuity-noncontinuity controversy as debated by Krechevsky (1932), Lashley (1942), and Spence (1936, 1937). The central issue as implied by the title of the controversy, as it became known, was whether learning was a continuous, gradual process (Spence), or whether learning was an all-or-none sudden process (Lashley and Krechevsky). Another issue which was debated centered upon whether learning was an active or passive process. While Krechevsky and Lashley viewed the animal in a discrimination task as actively searching and adopting one or another strategy until the correct solution was happened upon and used, Spence viewed the solution of a discrimination problem solved by an organism as a more passive process. Another topic of debate, which is the primary concern of this paper, was how animals made use of multiple cues in a discrimination task. Spence contended that learning took place about any stimulus which impinged upon the animal's sensorium at the moment of a response. Lashley contended that animals do not attend to all stimuli at once, and furthermore, that attention to one cue excluded attention to any other cue. As such, Lashley was committed to showing that nothing was learned about irrelevant, incidental cues when the response was already governed by other cues.

Although some support has been given to Lashley's first statement, that the more attention paid to one stimulus the less paid to other stimuli (Reynolds, 1961; Sutherland & Holgate, 1966; Sutherland & Mackintosh, 1964), particularly using a "blocking" paradigm (Kamin, 1969; Mackintosh, 1965), few researchers would adopt Lashley's stronger statement that no learning to incidental cues takes place. In fact, evidence overwhelmingly indicates that some incidental cue learning occurs. Blum and Blum (1949) indicated that animals learned more than a particular cue, and that at least in their experimentation, animals appeared to notice a change in an altered environment. Terrace (1963), in an often referenced article, reported responding to "faded in" cues even though responding was already under full control of another cue. Pigeons were responding to a red positive stimulus and not responding to a negative green stimulus when Terrace faded in a vertical stripe superimposed on the red key and a horizontal stripe superimposed on the green key. Gradually Terrace then faded out the color stimuli and found that responding was maintained to the vertical stimulus while little responding was evoked to the horizontal stimulus. Even using a blocking paradigm, researchers report learning about incidental cues (Bitterman & Coate, 1950; Hughes & North, 1959).

The Blocking Paradigm

Lashley (1942) used a technique in which he introduced and trained with one stimulus prior to introducing a second stimulus. After introducing a second stimulus and testing for stimulus control, Lashley reported that nothing was learned about the added dimension. Kamin (1969) later labelled this procedure as the "blocking" paradigm.

In a now classic demonstration of blocking, Kamin (1969) trained animals to bar press and then introduced either a white noise CS or a light CS in a conditioned emotional response (CER) procedure. In Stage II, Kamin presented the compound of the white noise and light CS's, and finally in a testing phase, he tested each stimulus under nonreinforcement conditions for amount of suppression to the bar press response. Kamin concluded that although animals appeared to learn little about incidental redundant stimuli at first glance, animals did learn something. Throughout the testing phase, animals at least noticed a change in the stimulus configuration, but they later ignored the added stimulus when it was discovered that the stimulus did not predict new information. An added stimulus, which did, in fact, predict new information, came to control responding. Kamin's interpretation was similar to the interpretation of the results of an experiment done by Egger and Miller (1962). Egger and Miller arranged the occurrence of one stimulus to precede the occurrence of a second stimulus. However, in one case the first stimulus never occurred without a subsequent UCS. The second stimulus was then a redundant predictor of information. In the second case, the first stimulus was occasionally presented without following it with a UCS. The second stimulus never occurred without a UCS. In this case, the second stimulus gained more control over behavior since it reliably predicted the UCS.

Sutherland and Mackintosh (1971) provide an excellent review of the blocking paradigm and its results. They list several factors that affect the amount of incidental cue learning in a blocking procedure. For example, the number of training trials prior to the addition of the second stimulus affects the amount learned about the second stimulus (Bruner, Matter & Papanek, 1955; Johnson & Cummings, 1968). A second factor which appears to affect the amount of incidental cue learning is drive level. Experimentation (Bruner et al.) indicates that increased drive level reduces the amount learned about incidental cues. Mackintosh (1965) gives evidence for a third factor which affects the amount learned about incidental cues. He trained rats to respond to a vertical-horizontal orientation of rectangles in the first stage of the experiment. For one group, Mackintosh used eight different shades of gray in training the rats for a subsequent brightness discrimination of black and white in Stage II. In another group, black and white cues were abruptly introduced at the start of Stage II. Mackintosh found that the group in which black and white were abruptly introduced learned more about the brightness discrimination than did the group for which black and white were gradually introduced. In the same experiment, Mackintosh also varied the length of horizontal and vertical lines in the rectangles. The closer the similarity between the horizontal and vertical rectangles, the more difficult was the discrimination, and subsequently, more was learned about the incidental cue. Hence, it appears that the more difficult the discrimination, the more an animal makes use of other available cues.

In summary, it appears that something is learned about incidental cues. However, the amount learned about incidental cues depends upon many other factors.

Concurrent Presentation with Multiple Cues

Although the blocking paradigm affords a degree of control to the experimenter in the study of stimulus selection, a great deal of experimentation is run where two or more cues are presented simultaneously. Here, too, several factors affect stimulus selection.

Pavlov (1927) was the first experimenter to report that the amount learned about cues presented simultaneously depended upon the strengths of contributing stimuli. Pavlov presented a compound of heat and tactile stimuli to the dogs in his laboratory. He found that the tactile stimulus "overshadowed" the heat stimulus. However, Wagner, Logan, Haberlandt, and Price (1968) showed that overshadowing is not a simple direct consequence of the more intense stimulus overshadowing the less intense stimulus. The reliability of a stimulus in predicting the occurrence of reinforcement contributes substantially to stimulus selection.

Overshadowing covers the case in which one stimulus is noticeably more intense than another stimulus. But rather than dealing with grossly obvious cases in which one stimulus is much more intense than another stimulus, most researchers assume an equality of intensity in dimensions frequently used by the animal, or the experimenters simply select stimuli assumed to be equal in strength. Reynolds (1961) trained pigeons to respond to a compound of color and shape; respond to a red triangle and not respond to a green circle. In testing for stimulus control, Reynolds found that responding was controlled in one pigeon by the color red, while responding in another pigeon was controlled by the triangular shape. Rather than inferring an inequality between dimensions within species, Reynolds preferred to attribute different preferences in responding as due to differences in the attention each pigeon paid to the components.

In both the blocking procedure and in the simultaneous presentation of stimuli, the selection of one stimulus over another has been continually pointed out, but that does not mean to imply that component learning is the only type of learning which the animal is capable of demonstrating. Although differential responding to different components of a stimulus complex is often found (Eckerman, 1967), there is also evidence which indicates that animals may learn to respond to the compound more than to the components alone (Butter, 1963). Butter accounted for his results by saying that there was less generalization to stimuli which varied in two dimensions than to stimuli which varied in one dimension. In essence, Butter was saying that the compound stimulus was more unique than the components, and, therefore, was more apt to evoke a higher degree of responding.

Whether animals respond more to components or to compounds depends upon the particular situation (determined by a wide variety of factors). What has been more clearly established by experimenters is that the presentation of more than one relevant cue appears to increase the speed with which the discrimination is obtained. Why this increase in speed is found is less certain. Many theorists assume an additivity of cues which contributes to the increase in speed of the discrimination while others assume a variety of explanations for the phenomenon. Sutherland and Mackintosh (1964), for example, explain the phenomenon by denying the additivity of cues, saying that the more an animal learns about one cue, the less he learns about another cue. The reason for the increase in speed of discrimination is that the animals have a greater selection of cues to which they may attend. Restle (1955, 1957, 1958) pointed out that additivity of cues implies independence of cues, and clearly many cues are not independent (e.g., brightness is not independent of hue). Other experimenters have assumed a multiplicative role rather than an additive role. Butter (1963), for one, states that the similarity between stimuli differing in several dimensions is a joint function of perceived similarity between stimuli within each relevant dimension.

In conclusion, a wide variety of factors appear to influence component and compound learning, blocking, and overshadowing. A theory which hopes to have any degree of predictive utility must be able to account for a variety of conditions.

Recent Theoretical Viewpoints

Theory in the last fifteen years has seen a renewal or a drudging up of some of the old issues in the continuity-noncontinuity controversy. One viewpoint has picked up the banner once carried by Lashley and Krechevsky. The central notion adopted by Lashley and Krechevsky was that the organism was actively involved in solving a discrimination problem. Krechevsky viewed the organism as actively selecting and trying different hypotheses until reaching the correct solution. Krechevsky stated that each animal was able to process only the information concerned with the particular hypothesis being tested. Central to recent selective attention theories is that there is also a limit to the amount of information which can be processed.

The Zeaman and House model (1963) is probably the most confining theory of selective attention. Selective attention, as viewed by Zeaman and House, states that behavior can be controlled by only one analyzer at a time. Reward increments the probability of switching in a particular analyzer again and decrements all other analyzers not switched in at that time. Nonreinforcement does not necessarily weaken the analyzer which was used, but rather serves to increment all other analyzers (which shows up as a loss in strength in the particular analyzer strength since the probability of using other analyzers has now been increased). Clearly, adopting the view that only one analyzer may be switched in at one time does not predict compound learning satisfactorily even if the organism were switching from one component to another component from trial to trial. Zeaman and House did suggest the possibility that more than one analyzer may be switched in at one time, and that the probability of this occurring was the product of each of these analyzers separately. However, Zeaman and House only suggest this possibility but do not attempt any analysis of their suggestion.

Restle (1955, 1957, 1958, 1962) also uses probabilites in accounting for discrimination learning. Restle contends that relevant cues are adapted in and that irrelevant cues are adapted out. The Restle model also suggests that conditioning valid cues to the response depends on the mean validity of the cues present (Wagner et al., 1968). Although the model accounts for discrimination learning when cues are clearly relevant or irrelevant, a selective attention notion must be adopted by Restle to account for adapting out of redundant cues. Functionally invalid cues (determined by low percentage of reinforcement) are also adapted out (But this cannot account for conditioned inhibition if such is always the case.).

A model of selective attention as viewed by Lovejoy (1965) also does not account for multiple cue learning or compound learning. Like the Zeaman and House model, Lovejoy's model states that only one analyzer at a time can control behavior on each trial. Rewarded trials also serve to increase the probability that the analyzer will again be switched in. However, Lovejoy's model differs from the Zeaman and House model in its account of nonreinforced trials. On nonrewarded trials, all analyzer values revert towards their starting values of trial one. Despite this elaboration, the Lovejoy model suffers from the same malady as does the Zeaman and House model. If behavior can only be controlled by one analyzer at a time, then two components of a compound cannot contribute to behavior at one time (again not accounting for conditioned inhibition).

There are certainly other accounts of selective attention (Broadbent, 1954; Lawrence, 1949; Mackintosh, 1965; Trabasso & Bower, 1968), but the most recent attempt to formulate a model for selective attention is that of Sutherland and Mackintosh (1971). In their model, Sutherland and Mackintosh differ from more simple views of previous attention theories. The Sutherland and Mackintosh model states that more than one analyzer may be used in determining behavior. Secondly, analyzer strength is not simply increased by reward and decreased by nonreward, but rather analyzer strength increases when an expected outcome occurs and decreases with the occurrence of an unexpected outcome. On trials where several cues correctly predict reward or nonreward, the cue which makes the strongest correct prediction is increased and all other analyzer strengths are decreased. By assuming that more than one analyzer may be used during a trial, the Sutherland-Mackintosh model of selective attention can account for compound learning, control of behavior by more than one analyzer, and for learning about several analyzers within a single trial. However, the Sutherland-Mackintosh model has not yet been completed since, as pointed out by the authors, the failures of the model have not made it worth further simulation. Some of the questions asked by Sutherland and Mackintosh demonstrate the incompleteness of the model. For example, can more than one analyzer be increased in strength at one time? In a two process model, does response strength help to determine which analyzers are increased or decreased? What determines whether more than one analyzer will come to control behavior? In short, although the model does show the development of a theory which can account for multiple cue learning, compound learning, and component learning, the model cannot predict which type of learning will occur or why it will occur.

Other attempts have been made to account for compound learning. These theories have been massed together for summarization purposes and through a common assumption held by each (Wagner & Rescorla, 1972). Several previous theories (Bush & Mosteller, 1951; Estes & Burke, 1953; Hull, 1943; Spence, 1936, 1952) have all assumed (in different terminology) that reinforcement increases associative strength, and nonreinforcement decreases associative strength. With repeated pairings of a stimulus with reinforcement or nonreinforcement, the associative value of the stimulus approaches some asymptotic level. The closer a stimulus is to its asymptotic level the smaller the increment or decrement due to reinforcement and nonreinforcement. In dealing with compounds and multiple stimuli, the above theories state that the associative strength of each component is modified until each reaches its own asymptotic level. This implies that components with different validities may show different levels in evoking responding.

A different view has been adopted by Wagner and Rescorla (1972). Wagner and Rescorla not only differ in their account of compound learning, but they also differ in their account of how associative strengths of stimuli are incremented and decremented. Experimentation by Kamin (1969) has altered the "modified continuity" theory once advanced by Wagner (1969). Contrary to the above "saturation" theories (Bush & Mosteller, 1951; Estes & Burke, 1953; Hull, 1943; Spence, 1936, 1952), Wagner and Rescorla assume that repeated pairings of a CS with a UCS produces smaller and smaller increments in associative strength, not because the CS becomes less and less capable of being incremented (saturation viewpoint), but because the UCS becomes less effective.

Furthermore, learning occurs when a stimulus is followed by an unexpected or surprising event (Learning occurs in the Sutherland-Mackintosh model when an expected outcome occurs. Both theories are similar in adopting the assumption that an active process of rehearsal (Wagner, Rudy, & Whitlow, 1972) occurs in relation to the expectations of the organism.).

In accounting for compound learning, the Wagner-Rescorla model assumes that the associative values of each component continue to change until the collective value of the compound reaches its asymptotic level. Since the Wagner-Rescorla model assumes that increments in associative value become smaller and smaller because the US becomes less effective as it is announced by a cue with increasing associative strength, it follows that when more than one stimulus is present on any trial, the associative strength of all stimuli present is incremented or decremented according to the surprisingness of the US. Once the compound predicts the occurrence of the US with a high degree of certainty, learning to all cues involved ceases because the US is no longer surprising.

Wagner and Rescorla have proposed a linear model in attempt to account for stimulus control. The change in associative value, $\Delta V_i = \alpha_i \beta_1 (\lambda_1 - \overline{V})$ where α_i is determined by the properties of the stimulus (e.g., cue saliency), β_1 and λ_1 are both determined by the properties of the reinforcement, λ_1 is the asymptotic level determined by the reinforcement, and $\overline{V}$ is determined by the aggregate associative strength of all stimuli present on that particular conditioning trial. Increments in signal value occur when ($\lambda_1 - \overline{V}$) is positive, and decrements occur when it is negative.

The Wagner-Rescorla model appears to be able to account for multiple cue learning without resorting to adopting an attention explanation. The model as proposed by Wagner and Rescorla differs from the Sutherland-Mackintosh model in that unexpected outcomes result in learning whereas expected outcomes determine learning in the Sutherland-Mackintosh model. Secondly, α in the Wagner-Rescorla model is a constant. If it were allowed to change, it would resemble an attentional notion as proposed by Sutherland and Mackintosh. In an attention theory, stimulus properties continually change since stimuli continue to compete for the attention of the animal.

The Wagner-Rescorla model can explain compound learning, multiple cue learning, and component learning quite well. One of the largest assets of the theory is its adaptability in accounting for both increments and decrements in associative strength under conditions of both reinforcement and nonreinforcement. However, the Wagner-Rescorla model also does not explicitly state when compound learning will be more likely to occur than component learning or vice-versa. The common assumption of many theories, as pointed out by Gardner and Coate (1965), is that reinforcement contributes more to learning than nonreinforcement. Hull (1943), for example, viewed nonreward as contributing only passively to learning. Evidence increasingly points out that nonreward should be viewed as contributing actively to learning (Amsel, 1962; Festinger, 1957; Pavlov, 1927; Rescorla, 1969; Spence, 1936; Wagner & Rescorla, 1972). The ease with which the Wagner-Rescorla theory handles the effects of nonreinforcement will be demonstrated in the context of conditioned inhibitor.

Conditioned Inhibition in an Instrumental Conditioning Paradigm

Pavlov (1926) defined a conditioned inhibitor (CI) as a stimulus which had acquired the capacity to reduce a conditioned response (CR) to an otherwise effective conditioned stimulus (CS). In a differential conditioning procedure, Pavlov presented the CS with the unconditioned stimulus (UCS) on some trials and presented the compound CS-CI without the UCS on other trials. The added stimulus was called a conditioned inhibitor because, after sufficient training, it came to reduce or completely block responding to a stimulus that was perfectly effective when presented alone.

Although the experimental literature contains many subsequent demonstrations of a conditioned inhibitor in classical conditioning, examples are relatively scarce in operant and instrumental conditioning. Indeed, when a conditioned inhibitor was demonstrated in operant and instrumental settings, it was usually through some prior Pavlovian discrimination training (Bower & Grusec, 1964) or in a conditioned suppression paradigm (Hendry, 1967). One reason for this scarcity was that the term "conditioned inhibitor" itself was a topic of debate. Skinner (1938) preferred to look at the reduction of responding to a compound due to one stimulus and the reduction of responding to another compound by the same stimulus as a result of generalized extinction. Skinner maintained that generalized extinction was primarily due to the similarity of the compound S_AS_B with S_CS_B and that these two compounds must be clearly distinguished from each other before the term conditioned inhibitor may be applied to S_B (if it does reduce responding to both S_A and S_C). Brown and Jenkins (1967) met with Skinner's objections in an experiment in which the S_A and S_C stimuli were clearly distinguishable key colors which maintained differential responding (peck right vs. peck left) throughout testing, and demonstrated a conditioned inhibitor within an operant setting.

However, the demonstration of a conditioned inhibitor within an instrumental setting has been even more difficult than in an operant setting. Rescorla (1969) has pointed out that the development of a conditioned inhibitor has not been clearly defined and has suggested two methods to measure conditioned inhibition. One of the methods of measurement compares the response to a known excitor (S_o), when presented alone, to the response of S_o and S_1 in compound. If S_1 reduces the tendency to respond to S_o, then S_1 is an inhibitor (summation technique).

The explanation of the development of a conditioned inhibitor implies that behavior is controlled by more than one stimulus. Early accounts of attention theory (Lovejoy, 1965; Mackintosh, 1965, Zeaman & House, 1963) assume that only one stimulus at a time can control behavior. To explain the results of a conditioned inhibitor, early attention theorists proposed a shift in attention from the +CS to the -CS, but at some juncture, the theorists must explain the reason for this shift from a previously attended cue to a nonattended cue.

The Wagner-Rescorla model proposes that positive signal value results when ($\lambda - \overline{V}$) is positive, and negative signal value results when the quantity is negative. For the quantity to become negative, the associative strength of the aggregate of all cues present ($\overline{V}$) must be more positive than the asymptotic value (λ). A conditioned inhibitor is a stimulus which has developed negative signal value due to nonreinforcement in a complex of cues which signal reinforcement.

Although the majority of supporting evidence (Rescorla & LoLordo, 1965; Wagner, 1971; Wagner & Rescorla, 1972) has been obtained with aversive stimuli, the theory suggests that conditioned inhibitors may be developed in appetitive situations.

The Direction of Theory

Although both the Sutherland-Mackintosh and Wagner-Rescorla theories do have some value in explaining various phenomena in discrimination learning, the ideal purpose of a theory is to predict the outcome of a problem beforehand. In other words, a workable theory of discrimination learning must not only be able to account for results after the experiment has been completed, but rather must be able to predict the outcome given a certain set of conditions. While both sets of theorists indicate that their theories are far from complete, the theories have nonetheless functioned to stimulate research and thinking.

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APPENDIX II

METHODOLOGY

Table 6

Semi-Random Order of Stimulus Presentations for
Conditions Ia and IIIa (No Light)

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1L	21.	T_1T_2	41.	T_2L	61.	T_3L	81.	T_1T_3	101.	T_3L
2.	T_1T_2	22.	T_2L	42.	T_2L	62.	T_1L	82.	T_2T_3	102.	T_1L
3.	T_1L	23.	T_2T_3	43.	T_3L	63.	T_2T_3	83.	T_2T_3	103.	T_1T_2
4.	T_2T_3	24.	T_2T_3	44.	T_1L	64.	T_1T_2	84.	T_1T_2	104.	T_1T_3
5.	T_2T_3	25.	T_1T_2	45.	T_2T_3	65.	T_1L	85.	T_1T_2	105.	T_2T_3
6.	T_3L	26.	T_1T_3	46.	T_3L	66.	T_1T_3	86.	T_1L	106.	T_1L
7.	T_1L	27.	T_1L	47.	T_1T_3	67.	T_1*	87.	T_3L	107.	T_1T_2
8.	T_2T_3	28.	T_2T_3	48.	T_1L	68.	T_1*	88.	T_1L	108.	T_2T_3
9.	T_1T_3	29.	T_2L	49.	T_2T_3	69.	T_1*	89.	T_1T_3	109.	T_2L
10.	T_2T_3	30.	T_1L	50.	T_2T_3	70.	T_1*	90.	T_1T_3	110.	T_1L
11.	T_2L	31.	T_2T_3	51.	T_2T_3	71.	T_1L	91.	T_1L	111.	T_3L
12.	T_1L	32.	T_1T_2	52.	T_1T_2	72.	T_2T_3	92.	L*	112.	T_3L
13.	T_1L	33.	T_1L	53.	T_3L	73.	T_1L	93.	L*	113.	T_1L
14.	T_2T_3	34.	T_1T_3	54.	T_3L	74.	T_3L	94.	L*	114.	T_2T_3
15.	T_2*	35.	T_1T_2	55.	T_2L	75.	T_2T_3	95.	L*	115.	T_2T_3
16.	T_2*	36.	T_1T_3	56.	T_1L	76.	T_1L	96.	T_2L	116.	T_2L
17.	T_2*	37.	T_3*	57.	T_3L	77.	T_2T_3	97.	T_1L	117.	T_3L
18.	T_2*	38.	T_3*	58.	T_2T_3	78.	T_1L	98.	T_1T_3	118.	T_1T_2
19.	T_1T_2	39.	T_3*	59.	T_2L	79.	T_2L	99.	T_2L	119.	T_2L
20.	T_1T_3	40.	T_3*	60.	T_1T_3	80.	T_2T_3	100.	T_1T_2	120.	T_1T_3

* presented only during the testing phase

Table 7

Semi-Random Order of Stimulus Presentations for Conditions Ib and IIIb (No Light)

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_2L	21.	T_2T_3	41.	T_1T_3	61.	T_2L	81.	T_2T_3	101.	T_1T_3
2.	T_2T_3	22.	T_1T_2	42.	T_1L	62.	T_3*	82.	T_2L	102.	T_2*
3.	T_2L	23.	T_2L	43.	T_1T_2	63.	T_3*	83.	T_1L	103.	T_2*
4.	T_1T_3	24.	T_1T_3	44.	T_2L	64.	T_3*	84.	T_2L	104.	T_2*
5.	T_1T_3	25.	L*	45.	T_1T_3	65.	T_3*	85.	T_1T_2	105.	T_2*
6.	T_1L	26.	L*	46.	T_1T_3	66.	T_1T_2	86.	T_1*	106.	T_2L
7.	T_2L	27.	L*	47.	T_1T_3	67.	T_2L	87.	T_1*	107.	T_2T_3
8.	T_3L	28.	L*	48.	T_2T_3	68.	T_1T_3	88.	T_1*	108.	T_1T_3
9.	T_1T_2	29.	T_2L	49.	T_1L	69.	T_2L	89.	T_1*	109.	T_3L
10.	T_1T_3	30.	T_3L	50.	T_1L	70.	T_1L	90.	T_1T_2	110.	T_2L
11.	T_3L	31.	T_1T_3	51.	T_3L	71.	T_1T_3	91.	T_2L	111.	T_1L
12.	T_2L	32.	T_2T_3	52.	T_2L	72.	T_2L	92.	T_3L	112.	T_1L
13.	T_2L	33.	T_2L	53.	T_1L	73.	T_1T_3	93.	T_2L	113.	T_2L
14.	T_1T_3	34.	T_1T_2	54.	T_1T_3	74.	T_2L	94.	T_1T_2	114.	T_1T_3
15.	T_2T_3	35.	T_2T_3	55.	T_3L	75.	T_3L	95.	T_3L	115.	T_1T_3
16.	T_1T_2	36.	T_1T_3	56.	T_1T_2	76.	T_1T_3	96.	T_2T_3	116.	T_3L
17.	T_2T_3	37.	T_3L	57.	T_1L	77.	T_1T_2	97.	T_1L	117.	T_1L
18.	T_3L	38.	T_3L	58.	T_2L	78.	T_1T_3	98.	T_2L	118.	T_2T_3
19.	T_1T_3	39.	T_1L	59.	T_1T_3	79.	T_1T_3	99.	T_2T_3	119.	T_3L
20.	T_1T_3	40.	T_2L	60.	T_2T_3	80.	T_2T_3	100.	T_1T_2	120.	T_1T_3

* presented only during the testing phase

Table 8

Semi-Random Order of Stimulus Presentations for Conditions Ic and IIIc (No Light)

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_3L	21.	T_1T_3	41.	T_1T_2	61.	T_2L	81.	T_1T_3	101.	T_1T_2
2.	T_1T_3	22.	T_2T_3	42.	T_2L	62.	T_3L	82.	T_3L	102.	T_3L
3.	T_3L	23.	T_3L	43.	T_2T_3	63.	T_1T_2	83.	T_2L	103.	T_1T_3
4.	T_1T_2	24.	T_1T_2	44.	T_3L	64.	T_1T_3	84.	T_3L	104.	T_1T_2
5.	T_1T_2	25.	T_3*	45.	T_1T_2	65.	T_3L	85.	T_2T_3	105.	T_1L
6.	T_2L	26.	T_3*	46.	T_1T_2	66.	T_2T_3	86.	T_2T_3	106.	T_3L
7.	T_3L	27.	T_3*	47.	T_1T_2	67.	T_3L	87.	T_3L	107.	T_2L
8.	T_1T_2	28.	T_3*	48.	T_1T_3	68.	T_1T_2	88.	T_1L	108.	T_2*
9.	T_2T_3	29.	T_3L	49.	T_2L	69.	T_3L	89.	T_3L	109.	T_2*
10.	T_1T_2	30.	T_1L	50.	T_2L	70	T_2L	90	L*	110.	T_2*
11.	T_1L	31.	T_1T_2	51.	T_1L	71.	T_1T_2	91.	L*	111.	T_2*
12.	T_3L	32.	T_1T_3	52.	T_3L	72.	T_3L	92.	L*	112.	T_2L
13.	T_3L	33.	T_3L	53.	T_2L	73.	T_1T_2	93.	L*	113.	T_3L
14.	T_1T_2	34.	T_2T_3	54.	T_1T_2	74.	T_3L	94.	T_2T_3	114.	T_1T_2
15.	T_1T_3	35.	T_1T_3	55.	T_1*	75.	T_1L	95.	T_1L	115.	T_1T_2
16.	T_2T_3	36.	T_1T_2	56.	T_1*	76.	T_1T_2	96.	T_1T_3	116.	T_1L
17.	T_1T_3	37.	T_1L	57.	T_1*	77.	T_2T_3	97.	T_2L	117.	T_2L
18.	T_1L	38.	T_1L	58.	T_1*	78.	T_1T_2	98.	T_3L	118.	T_1T_3
19.	T_1T_2	39.	T_2L	59.	T_1L	79.	T_1T_2	99.	T_1T_3	119.	T_1L
20.	T_1T_2	40.	T_3L	60	T_2T_3	80.	T_1T_3	100.	T_2T_3	120.	T_2T_3

* presented only during the testing phase

Table 9

Semi-Random Order of Stimulus Presentations for
Condition IIa and Replication IIa

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_2T_3	20.	T_1L	39.	T_1L	58.	T_3L	77.	T_1*	96.	T_1L
2.	T_1T_2	21.	T_1L	40.	T_2T_3	59.	T_1L	78.	T_2T_3	97.	T_1T_2
3.	T_2T_3	22.	T_2T_3	41.	T_1L	60.	T_1L	79.	T_1L	98.	T_2T_3
4.	T_3L	23.	T_3*	42.	T_2T_3	61.	T_2T_3	80.	T_1T_3	99.	T_1L
5.	T_1L	24.	T_3*	43.	T_1T_3	62.	T_1T_2	81.	T_1L	100.	T_2*
6.	T_1T_3	25.	T_3*	44.	T_2T_3	63.	T_1L	82.	T_2L	101.	T_2*
7.	T_2T_3	26.	T_3*	45.	T_2T_3	64.	T_2T_3	83.	T_2T_3	102.	T_2*
8.	T_2T_3	27.	T_1T_2	46.	T_2L	65.	T_1T_3	84.	T_1L	103.	T_2*
9.	T_1L	28.	T_2T_3	47.	T_2T_3	66.	T_1L	85.	T_2T_3	104.	T_2T_3
10.	T_2T_3	29.	T_1L	48.	T_2T_3	67.	T_1L	86.	T_1L	105.	T_2T_3
11.	T_3L	30.	T_2T_3	49.	L*	68.	T_2T_3	87.	T_1L	106.	T_1L
12.	T_1L	31.	T_2T_3	50.	L*	69.	T_2L	88.	T_2T_3	107.	T_2T_3
13.	T_1L	32.	T_1L	51.	L*	70.	T_1L	89.	T_3L	108.	T_1L
14.	T_2L	33.	T_1L	52.	L*	71.	T_1T_3	90.	T_2T_3	109.	T_1L
15.	T_2T_3	34.	T_2T_3	53.	T_1L	72.	T_1L	91.	T_3L	110.	T_1T_2
16.	T_1L	35.	T_2L	54.	T_2L	73.	T_1T_2	92.	T_1L	111.	T_2T_3
17.	T_1L	36.	T_2T_3	55.	T_2T_3	74.	T_1*	93.	T_2T_3	112.	T_2T_3
18.	T_2T_3	37.	T_1T_3	56.	T_1L	75.	T_1*	94.	T_1L	113.	T_1L
19.	T_3L	38.	T_1L	57.	T_2T_3	76.	T_1*	95.	T_1L	114.	T_2T_3

* presented only during the testing phase

Table 10

Semi-Random Order of Stimulus Presentations for Condition IIb and Replication IIb

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1T_3	20.	T_2L	39.	T_2L	58.	T_3L	77.	T_2*	96.	T_2L
2.	T_1T_2	21.	T_2L	40.	T_1T_3	59.	T_2L	78.	T_2*	97.	T_2L
3.	T_1T_3	22.	T_1T_3	41.	T_2L	60.	T_2L	79.	T_1T_3	98.	T_1T_2
4.	T_3L	23.	T_3*	42.	T_1T_3	61.	T_1T_3	80.	T_2L	99.	T_1T_3
5.	T_2L	24.	T_3*	43.	T_2T_3	62.	T_1T_2	81.	T_2T_3	100.	T_2L
6.	T_2T_3	25.	T_3*	44.	T_1T_3	63.	T_2L	82.	T_1T_3	101.	T_1*
7.	T_1T_3	26.	T_3*	45.	T_1T_3	64.	T_1T_3	83.	T_1L	102.	T_1*
8.	T_1T_3	27.	T_1T_2	46.	T_1L	65.	T_1T_3	84.	T_1T_3	103.	T_1*
9.	T_2L	28.	T_1T_3	47.	T_1T_3	66.	T_2T_3	85.	T_2L	104.	T_1*
10.	T_1T_3	29.	T_2L	48.	T_1T_3	67.	T_2L	86.	T_1T_3	105.	T_1T_3
11.	T_3L	30.	T_1T_3	49.	L*	68.	T_2L	87.	T_2L	106.	T_1T_3
12.	T_2L	31.	T_1T_3	50.	L*	69.	T_1T_3	88.	T_2L	107.	T_2L
13.	T_2L	32.	T_2L	51.	L*	70.	T_1L	89.	T_1T_3	108.	T_1T_3
14.	T_1L	33.	T_2L	52.	L*	71.	T_2L	90.	T_3L	109.	T_2L
15.	T_1T_3	34.	T_1T_3	53.	T_2L	72.	T_1T_3	91.	T_1T_3	110.	T_2L
16.	T_2L	35.	T_1L	54.	T_1L	73.	T_2L	92.	T_3L	111.	T_1T_2
17.	T_2L	36.	T_1T_3	55.	T_1T_3	74.	T_1T_2	93.	T_2L	112.	T_1T_3
18.	T_1T_3	37.	T_2T_3	56.	T_2L	75.	T_2*	94.	T_1T_3	113.	T_1T_3
19.	T_3L	38.	T_2L	57.	T_1T_3	76.	T_2*	95.	T_2L	114.	T_2L

* presented only during the testing phase

Table 11

Semi-Random Order of Stimulus Presentations for Condition IIc and Replication IIc

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1T_2	20.	T_3L	39.	T_3L	58.	T_1L	77.	T_3*	96.	T_3L
2.	T_1T_3	21.	T_3L	40.	T_1T_2	59.	T_3L	78.	T_3*	97.	T_1T_3
3.	T_1T_2	22.	T_1T_2	41.	T_3L	60.	T_3L	79.	T_1T_2	98.	T_1T_2
4.	T_1L	23.	T_1*	42.	T_1T_2	61.	T_1T_2	80.	T_3L	99.	T_3L
5.	T_3L	24.	T_1*	43.	T_2T_3	62.	T_1T_3	81.	T_2T_3	100.	T_2*
6.	T_2T_3	25.	T_1*	44.	T_1T_2	63.	T_3L	82.	T_3L	101.	T_2*
7.	T_1T_2	26.	T_1*	45.	T_1T_2	64.	T_1T_2	83.	T_2L	102.	T_2*
8.	T_1T_2	27.	T_1T_3	46.	T_2L	65.	T_1T_2	84.	T_1T_2	103.	T_2*
9.	T_3L	28.	T_1T_2	47.	T_1T_2	66.	T_2T_3	85.	T_3L	104.	T_1T_2
10.	T_1T_2	29.	T_1T_2	48.	T_1T_2	67.	T_3L	86.	T_1T_2	105.	T_1T_2
11.	T_1L	30.	T_3L	49.	L*	68.	T_3L	87.	T_3L	106.	T_3L
12.	T_3L	31.	T_1T_2	50.	L*	69.	T_1T_2	88.	T_1T_2	107.	T_1T_2
13.	T_3L	32.	T_3L	51.	L*	70.	T_2L	89.	T_1L	108.	T_3L
14.	T_2L	33.	T_3L	52.	L*	71.	T_3L	90.	T_1T_2	109.	T_3L
15.	T_1T_2	34.	T_1T_2	53.	T_3L	72.	T_2T_3	91.	T_1L	110.	T_1T_3
16.	T_3L	35.	T_2L	54.	T_2L	73.	T_3L	92.	T_3L	111.	T_1T_2
17.	T_3L	36.	T_1T_2	55.	T_1T_2	74.	T_1T_3	93.	T_1T_2	112.	T_1T_2
18.	T_1T_2	37.	T_2T_3	56.	T_3L	75.	T_3*	94.	T_3L	113.	T_3L
19.	T_1L	38.	T_3L	57.	T_1T_2	76.	T_3*	95.	T_3L	114.	T_3L

* presented only during the testing phase

Table 12

Semi-Random Order of Stimulus Presentations for Conditions IVa & IVb* and Extensions IIIa & IIIb*

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1T_2	18.	T_1T_2	34.	T_1T_2
2.	T_1	19.	T_2	35.	T_1
3.	T_1T_2	20.	T_1	36.	T_1
4.	T_2	21.	T_1	37.	T_1
5.	T_1T_2	22.	T_1	38.	T_1T_2
6.	T_1	23.	T_1T_2	39.	T_2
7.	T_1T_2	24.	T_1T_2	40.	T_1T_2
8.	T_1	25.	T_1	41.	T_1T_2
9.	T_1	26.	T_1	42.	T_1T_2
10.	T_1	27.	T_2	43.	T_1
11.	T_2	28.	T_1	44.	T_1T_2
12.	T_1T_2	29.	T_1T_2	45.	T_1T_2
13.	T_1	30.	T_2	46.	T_2
14.	T_1T_2	31.	T_1T_2	47.	T_1
15.	T_1	32.	T_1	48.	T_1T_2
16.	T_1T_2	33.	T_1	49.	T_1T_2
17.	T_1				

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* In Condition IVb and Extension IVb, T_2 was replaced by T_3 in the above order.

Table 13

Semi-Random Order of Stimulus Presentations for Conditions IVc & IVd* and Extensions IIIc & IIId*

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1T_2	18.	T_1T_2	34.	T_1T_2
2.	T_2	19.	T_1	35.	T_2
3.	T_1T_2	20.	T_2	36.	T_2
4.	T_1	21.	T_2	37.	T_2
5.	T_1T_2	22.	T_2	38.	T_1T_2
6.	T_2	23.	T_1T_2	39.	T_1
7.	T_1T_2	24.	T_1T_2	40.	T_1T_2
8.	T_2	25.	T_2	41.	T_1T_2
9.	T_2	26.	T_2	42.	T_1T_2
10.	T_2	27.	T_1	43.	T_2
11.	T_1	28.	T_2	44.	T_1T_2
12.	T_1T_2	29.	T_1T_2	45.	T_1T_2
13.	T_2	30.	T_1	46.	T_1
14.	T_1T_2	31.	T_1T_2	47.	T_2
15.	T_2	32.	T_2	48.	T_1T_2
16.	T_1T_2	33.	T_2	49.	T_1T_2
17.	T_2				

* In Condition IVd and Extension IIId, T_1 was replaced by T_3 in the above order.

Table 14

Semi-Random Order of Stimulus Presentations for
Conditions IVe & IVf* and Extensions IIIe & IIIf*

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_1T_3	18.	T_1T_3	34.	T_1T_3
2.	T_3	19.	T_1	35.	T_3
3.	T_1T_3	20.	T_3	36.	T_3
4.	T_1	21.	T_3	37.	T_3
5.	T_1T_3	22.	T_3	38.	T_1T_3
6.	T_3	23.	T_1T_3	39.	T_1
7.	T_1T_3	24.	T_1T_3	40.	T_1T_3
8.	T_3	25.	T_3	41.	T_1T_3
9.	T_3	26.	T_3	42.	T_1T_3
10.	T_3	27.	T_1	43.	T_3
11.	T_1	28.	T_3	44.	T_1T_3
12.	T_1T_3	29.	T_1T_3	45.	T_1T_3
13.	T_3	30.	T_1	46.	T_1
14.	T_1T_3	31.	T_1T_3	47.	T_3
15.	T_3	32.	T_3	48.	T_1T_3
16.	T_1T_3	33.	T_3	49.	T_1T_3
17.	T_3				

* In Condition IVf and Extension IIIf, T_1 was replaced by T_2 in the above order.

Table 15

Semi-Random Order of Stimulus Presentations for Conditions Va and Vb*

TRIAL	STIM	TRIAL	STIM	TRIAL	STIM
1.	T_3L	18.	T_3L	34.	T_3L
2.	L	19.	T_3	35.	L
3.	T_3L	20.	L	36.	L
4.	T_3	21.	L	37.	L
5.	T_3L	22.	L	38.	T_3L
6.	L	23.	T_3L	39.	T_3
7.	T_3L	24.	T_3L	40.	T_3L
8.	L	25.	L	41.	T_3L
9.	L	26.	L	42.	T_3L
10.	L	27.	T_3	43.	L
11.	T_3	28.	L	44.	T_3L
12.	T_3L	29.	T_3L	45.	T_3L
13.	L	30.	T_3	46.	T_3
14.	T_3L	31.	T_3L	47.	L
15.	L	32.	L	48.	T_3L
16.	T_3L	33.	L	49.	T_3L
17.	L				

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* In Condition Vb, L was replaced by T_3, and T_3 was replaced by L in the above order.

APPENDIX III-A

RAW DATA

Table 16

Percent Responding to Stimuli in Conditions Ia, Ib, and Ic

Animals

Stimulus	Day	Condition Ia				Condition Ib				Condition Ic		
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#12
T_1L	1	0.250	0.000	0.154	0.273	0.000	0.000	0.154	0.083	0.000	0.000	0.000
	2	0.167	0.000	0.000	0.111	0.000	0.000	0.091	0.182	0.143	0.000	0.083
	3	0.000	0.077	0.000	0.154	0.077	0.077	0.154	0.231	0.130	0.080	0.000
T_1	1	0.500	1.000	0.500	1.000	0.500	0.750	0.000	0.667	0.500	0.500	0.500
	2	1.000	0.750	0.500	1.000	0.667	1.000	0.333	0.750	0.333	0.500	0.750
	3	0.750	0.750	0.750	1.000	1.000	1.000	0.000	0.667	0.750	1.000	0.667
T_2L	1	0.000	0.077	0.417	0.077	0.160	0.000	0.458	0.348	0.300	0.100	0.167
	2	0.000	0.000	0.308	0.273	0.043	0.000	0.333	0.364	0.100	0.083	0.154
	3	0.182	0.385	0.083	0.000	0.130	0.038	0.333	0.524	0.200	0.333	0.083
T_2	1	1.000	1.000	1.000	0.500	0.500	0.750	1.000	0.750	1.000	1.000	1.000
	2	1.000	1.000	1.000	0.500	1.000	1.000	1.000	1.000	0.750	1.000	1.000
	3	1.000	1.000	1.000	0.250	1.000	1.000	1.000	1.000	1.000	0.333	1.000
T_3L	1	0.231	0.077	0.345	0.130	0.545	0.308	0.250	0.417	0.545	0.308	0.167
	2	0.182	0.038	0.160	0.174	0.364	0.083	0.462	0.667	0.538	0.154	0.182
	3	0.130	0.083	0.240	0.164	0.333	0.154	0.500	0.667	0.571	0.111	0.308
T_3	1	1.000	0.750	1.000	0.500	1.000	1.000	1.000	0.750	1.000	0.750	0.750
	2	1.000	1.000	0.750	0.500	1.000	1.000	1.000	0.500	0.750	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
L	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250
	3	0.000	0.000	0.000	0.000	0.000	0.333	0.250	0.000	0.000	0.000	0.000

Table 17

Percent Responding to Stimuli in Conditions IIa, IIb, and IIc

Animals

		Condition IIa				Condition IIb				Condition IIc			
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
T_1L	1	0.030	0.060	0.027	0.060	0.166	0.000	0.000	0.200	0.166	0.800	0.200	0.200
	2	0.000	0.031	0.057	0.000	0.333	0.166	0.333	0.000	0.000	0.600	0.200	0.200
	3		0.056	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.166
T_1	1	1.000	1.000	0.500	0.250	1.000	1.000	1.000	0.750	1.000	1.000	0.333	0.500
	2	0.000	0.500	1.000	0.750	0.500	0.750	0.750	1.000	1.000	1.000	0.750	0.500
	3		0.750	1.000	1.000	0.500	1.000	1.000	0.500	1.000	1.000	1.000	0.750
T_2L	1	0.000	0.000	0.166	0.200	0.147	0.058	0.111	0.096	0.333	0.166	0.000	0.400
	2	0.000	0.166	0.166	0.000	0.055	0.054	0.162	0.054	0.166	0.166	0.333	0.000
	3		0.000	0.166	0.200	0.055	0.000	0.054	0.027	0.166	0.166	0.500	0.166
T_2	1	0.500	0.666	1.000	0.750	1.000	1.000	1.000	0.500	0.750	1.000	1.000	0.667
	2	0.250	0.750	1.000	1.000	0.750	1.000	1.000	0.750	1.000	1.000	1.000	0.750
	3		1.000	1.000	0.750	1.000	0.750	1.000	0.250	1.000	0.750	1.000	1.000
T_3L	1	0.166	0.000	0.333	0.833	0.833	0.166	0.333	0.600	0.114	0.066	0.080	0.125
	2	0.000	0.000	0.200	0.166	0.500	0.333	0.500	0.333	0.171	0.054	0.111	0.117
	3		0.000	0.000	0.500	0.166	0.000	0.333	0.500	0.085	0.055	0.000	0.000
T_3	1	0.750	1.000	1.000	1.000	1.000	1.000	0.750	0.333	0.750	1.000	0.750	0.500
	2	1.000	0.750	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.750
	3		0.750	1.000	0.750	1.000	0.750	1.000	1.000	0.500	0.750	1.000	0.500
L	1	0.000	0.250	0.000	0.000	0.250	0.000	0.000	0.000	0.333	0.000	0.000	0.000
	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.333
	3		0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 18

Percent Responding to Stimuli in Conditions IIIa, IIIb, and IIIc

Animals

		Condition IIIa				Condition IIIb				Condition IIIc			
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
T_1T_2	1	0.923	1.000	0.833	1.000	1.000	1.000	1.000	0.636	1.000	1.000	1.000	1.000
	2	0.923	1.000	0.750	1.000	0.769	1.000	1.000	0.833	0.956	0.960	0.916	0.960
	3	1.000	0.923	0.700	1.000	0.923	0.923	1.000	0.923	1.000	1.000	1.000	0.960
T_1T_3	1	1.000	0.923	0.700	1.000	1.000	0.958	1.000	0.736	0.916	0.923	1.000	0.692
	2	1.000	0.923	0.667	1.000	0.920	1.000	1.000	0.782	1.000	1.000	1.000	1.000
	3	1.000	0.923	0.583	1.000	0.960	0.952	0.875	0.920	0.909	1.000	1.000	1.000
T_2T_3	1	1.000	1.000	0.789	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.923
	2	1.000	0.954	0.861	1.000	0.818	1.000	1.000	1.000	1.000	0.846	1.000	0.846
	3	0.960	1.000	0.782	1.000	1.000	1.000	1.000	0.916	0.846	1.000	1.000	0.846
T_1	1	0.640	0.667	0.560	0.782	0.769	0.846	1.000	0.750	0.538	1.000	1.000	1.000
	2	0.840	0.772	0.476	0.807	0.833	0.909	1.000	0.692	0.583	1.000	1.000	0.846
	3	0.680	0.800	0.590	0.800	0.692	0.750	0.923	0.909	0.615	1.000	1.000	0.923
T_2	1	1.000	0.727	0.545	1.000	0.920	0.750	0.923	0.695	0.923	0.833	1.000	0.923
	2	1.000	0.846	0.818	1.000	0.913	0.807	0.956	0.384	1.000	0.769	1.000	0.769
	3	0.900	0.916	0.667	1.000	0.920	0.667	0.900	0.565	0.923	1.000	1.000	0.846
T_3	1	1.000	0.833	0.750	0.923	1.000	0.916	1.000	0.916	0.923	0.884	0.800	0.592
	2	1.000	1.000	0.833	0.846	0.916	1.000	1.000	1.000	0.916	0.884	0.714	0.461
	3	1.000	1.000	0.538	0.615	1.000	1.000	1.000	0.909	0.880	0.769	0.880	0.500

Table 19

Percent Responding to Stimuli in Conditions IVa, IVb, IVc, IVd, IVe, and IVf

Animals

		Conditions				Conditions				Conditions			
		IVa		IVb		IVc		IVd		IVe		IVf	
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
T_1T_2	1					0.882	0.592					1.000	0.938
	2					0.894	0.333					1.000	0.933
	3					0.875	0.586					0.952	1.000
T_1T_3	1			0.947	0.895					0.933	0.952		
	2			1.000	0.761					1.000	0.947		
	3			0.944	0.904					0.938	0.905		
T_2T_3	1	1.000	1.000					0.900	0.952				
	2	1.000	0.850					0.857	0.941				
	3	1.000	0.950					0.842	0.938				
T_1	1			0.833	0.667	0.857	0.833			0.631	0.190	0.952	1.000
	2			0.400	0.166	1.000	0.600			0.470	0.190	1.000	1.000
	3			0.142	0.142	0.333	0.571			0.470	0.222	0.952	0.941
T_2	1	0.571	0.667			0.889	0.412	0.450	0.350			1.000	1.000
	2	0.428	0.571			0.812	0.200	0.578	0.667			1.000	0.714
	3	0.500	0.333			0.555	0.400	0.526	0.647			1.000	1.000
T_3	1	1.000	0.944	0.938	0.952			1.000	1.000	1.000	1.000		
	2	1.000	0.900	1.000	0.700			1.000	1.000	0.667	0.833		
	3	0.950	0.900	0.750	0.761			1.000	1.000	0.667	0.857		

Table 20

Percent Responding to Stimuli in Conditions Va and Vb

		Animals							
		Condition Va				Condition Vb			
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8
T_3L	1	0.974	0.610	0.976	0.921	0.929	0.821	0.950	0.976
	2	0.976	0.780	1.000	0.929	0.976	0.875	0.905	0.952
	3	1.000	0.810	0.976	1.000	0.974	0.902	0.952	0.925
T_3	1	0.846	0.286	0.923	0.929	0.075	0.293	0.225	0.476
	2	0.786	0.429	1.000	0.786	0.143	0.366	0.049	0.436
	3	0.929	0.286	0.786	0.929	0.286	0.282	0.098	0.333
L	1	0.071	0.214	0.512	0.167	0.786	0.308	0.615	0.500
	2	0.048	0.190	0.238	0.171	0.429	0.385	0.429	0.500
	3	0.231	0.341	0.225	0.075	0.750	0.308	0.571	0.357

Table 21

Percent Responding to Stimuli in Replication of Condition II

Animals

		Condition IIa				Condition IIb				Condition IIc			
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
T_1L	1	0.000	0.058	0.083	0.135	0.000	0.000	0.000	0.166	0.000	0.333	0.200	1.000
	2	0.000	0.058	0.111	0.250	0.166	0.166	0.200	0.800	0.000	0.666	0.333	1.000
	3	0.000	0.083	0.000	0.333	0.200	0.333	0.000	0.500	0.000	0.666	0.333	1.000
T_1	1	1.000	0.750	0.500	0.000	0.750	1.000	0.500	0.250	1.000	1.000	0.750	1.000
	2	0.500	1.000	0.500	0.250	0.250	0.667	1.000	1.000	1.000	1.000	1.000	0.667
	3	0.750	0.750	0.000	0.500	1.000	0.333	1.000	0.750	1.000	1.000	1.000	0.750
T_2L	1	0.166	0.500	0.500	1.000	0.083	0.060	0.057	0.305	0.166	0.333	0.000	1.000
	2	0.000	0.500	0.667	1.000	0.088	0.294	0.171	0.459	0.000	0.166	0.000	1.000
	3	0.166	0.400	0.250	1.000	0.135	0.000	0.088	0.555	0.000	0.333	0.000	1.000
T_2	1	1.000	1.000	1.000	1.000	1.000	0.000	1.000	0.500	1.000	1.000	0.250	1.000
	2	1.000	1.000	1.000	0.750	1.000	0.500	1.000	0.750	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	0.750	1.000	0.667	1.000	0.000	1.000	1.000	1.000	1.000
T_3L	1	0.500	0.800	0.833	1.000	0.830	0.500	0.166	0.667	0.055	0.060	0.027	0.363
	2	0.333	0.333	0.667	1.000	0.667	0.400	0.166	1.000	0.177	0.027	0.222	0.264
	3	0.667	0.600	0.600	1.000	0.833	0.400	0.333	1.000	0.083	0.027	0.027	0.529
T_3	1	1.000	1.000	1.000	1.000	1.000	0.500	1.000	1.000	1.000	1.000	0.250	0.333
	2	1.000	1.000	1.000	1.000	1.000	0.750	1.000	1.000	1.000	1.000	0.750	0.333
	3	1.000	1.000	1.000	1.000	1.000	0.500	1.000	1.000	1.000	0.750	1.000	1.000
L	1	0.000	0.000	0.250	0.000	0.000	0.250	0.000	0.000	0.250	0.000	0.000	0.000
	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 22

Percent Responding to Stimuli in an Extension of Condition III

Animals

		Extension				Extension				Extension			
		IIIa		IIIb		IIIc		IIId		IIIe		IIIf	
Stimulus	Day	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
T_1T_2	1			1.000	1.000	1.000			1.000				
	2			1.000	1.000	1.000			1.000				
	3			1.000	1.000	1.000			0.900				
T_1T_3	1	1.000	0.904									1.000	1.000
	2	1.000	0.714									1.000	1.000
	3	1.000	0.857									1.000	0.952
T_2T_3	1						1.000	1.000		0.950	1.000		
	2						1.000	1.000		1.000	1.000		
	3						1.000	1.000		0.947	1.000		
T_1	1	0.095	0.500	0.833	0.576	0.857			1.000			1.000	0.857
	2	0.100	0.350	0.823	0.471	1.000			1.000			1.000	1.000
	3	0.000	0.200	0.650	0.400	0.833			1.000			0.857	1.000
T_2	1			1.000	1.000	1.000	0.352	0.381	0.952	1.000	1.000		
	2			0.800	1.000	1.000	0.524	0.684	0.950	0.571	1.000		
	3			0.857	1.000	1.000	0.333	0.333	1.000	1.000	1.000		
T_3	1	1.000	1.000				1.000	1.000		0.750	0.857	0.714	0.142
	2	1.000	0.714				1.000	1.000		0.700	0.857	0.619	0.380
	3	1.000	1.000				1.000	1.000		0.529	0.761	0.450	0.238

APPENDIX III-B

STATISTICAL ANALYSIS

Table 23

Analysis of Variance Summary Table for Condition I

Source	SS	df	MS	F
Total	29.127	197	--	---
Tones (T)	1.702	2	.851	11.197**
error	1.520	20	.076	---
Days (D)	.194	2	.077	1.764
error	1.107	20	.055	---
Light (L)	20.356	1	20.356	145.400**
error	1.402	10	.140	---
T X D	.073	4	.018	1.800
error	.380	40	.010	---
D X L	.019	2	.010	1.250
error	.156	20	.008	---
T X L	.064	2	.032	1.067
error	.600	20	.030	---
T X D X L	.023	4	.006	.194
error	1.231	40	.031	---
S/TDL	.300	10	.030	---

---

* $p < .05$
** $p < .01$

Table 24

Analysis of Variance Summary Table for Condition II

Source	SS	df	MS	F
Total	.503	23	--	---
Between	.391	11	--	---
Conditions (C)	.033	2	.016	0.410
Error (b)	.358	9	.039	---
Within	.112	12	--	---
Treatments (T)	.038	1	.038	6.333*
T X C	.015	2	.007	1.166
Error (w)	.059	9	.006	---

---

* $p < .05$

**$p < .01$

Table 25

Analysis of Variance Summary Table for Condition III

Source	SS	df	MS	F
Total	.430	23	--	---
Between	.209	11	--	---
Conditions (C)	.016	2	.008	.380
Error (b)	.193	9	.021	---
Within	.221	12	--	---
Treatments (T)	.115	1	.115	10.454**
T X C	.001	2	.0005	.454
Error (w)	.105	9	.011	---

---

* $p < .05$
**$p < .01$

Table 26

Analysis of Variance Summary Table for Condition IV

Source	SS	df	MS	F
Total	1.583	23	--	---
Between	.555	11	--	---
Conditions (C)	.423	5	.085	3.864
Error (b)	.132	6	.022	---
Within	1.028	12	--	---
Treatments (T)	.054	1	.054	2.571
T X C	.851	5	.170	8.095*
Error (w)	.123	6	.021	---

---

* $p < .05$

**$p < .01$

Table 27

Analysis of Variance Summary Table for Condition V

Source	SS	df	MS	F
Total	1.090	15	--	---
Between	.167	7	--	---
Conditions (C)	.039	1	.039	1.857
Error (b)	.128	6	.021	---
Within	.923	8	--	---
Treatments (T)	.600	1	.600	15.385**
T X C	.090	1	.090	2.308
Error (w)	.233	6	.039	---

---

* $p < .05$
**$p < .01$

Table 28

Analysis of Variance Summary Table for Replication of Condition II

Source	SS	df	MS	F
Total	1.314	23	--	---
Between	.620	11	--	---
Conditions (C)	.057	2	.028	.451
Error (b)	.563	9	.062	---
Within	.694	12	--	---
Treatments (T)	.315	1	.315	11.666**
T X C	.131	2	.065	2.407
Error (w)	.248	9	.027	---

---

* $p < .05$
**$p < .01$

Table 29

Analysis of Variance Summary Table for Extension of Condition III

Source	SS	df	MS	F
Total	1.823	23	--	---
Between	.423	11	--	---
Conditions (C)	.352	5	.070	5.833*
Error (b)	.071	6	.012	---
Within	1.400	12	--	---
Treatments (T)	.887	1	.887	49.278**
T X C	.406	5	.081	4.500*
Error (w)	.107	6	.018	---

---

* $p < .05$
**$p < .01$

APPENDIX IV

ADDITIONAL DATA: A REPLICATION OF CONDITION II AND AN EXTENSION OF CONDITION III

REPLICATION OF CONDITION II

Since Condition I and Condition II produced discrepant results, another experiment was run with the intent to replicate Condition II. Perhaps the results of Condition II, which produced differential responding due to different percentages of reinforcement, could be explained as a chance result leading to the rejection of the null hypothesis.

METHOD

Subjects. 12 female albino rats born and raised in the animal colony at the University of New Mexico were used. Each rat was naive and 120 days old at the start of the experiment. Rats were taken down to and maintained at 80% of their ad lib body weight throughout the experiment.

Apparatus. Same apparatus.

Procedure. The same procedure as used in Condition II was used in this experiment.

RESULTS AND DISCUSSION

Figure 11 shows the acquisition data of the replication of Condition II. Percent responding to tone-tone compounds increased over days while percent responding to tone-light compounds decreased over days (top graph). The bottom graph of Figure 11 indicates that percent correct responding increased over days as well as the percentage of responding done only during the stimulus presentation interval.

When the data was submitted to a within-Ss analysis of variance (reinforcement X groups), the difference between the 75% reinforced tones and the 25% reinforced tones was significant (F (1,9) = 11.666, $p < .01$.). Again neither the group effect (F (2,9) = .451) nor the reinforcement by group interaction (F (2,9) = 2.407) proved to be significant. Table 11 shows the data from which the analysis of variance was performed.

The data were averaged across testing days for each stimulus in each group and graphed as shown in Figure 12. In the top graph, the data for Group I demonstrated that T_1, the 25% reinforced tone, had a lower percentage of responding compared to T_2 and T_3, both 75% reinforced tones. Results from Group II (second bar graph) demonstrated T_2 was lower in response percentage than T_1 or T_3 as expected, and for Group III, the bottom bar graph, T_3 was lower than both T_1 and T_2. Like Condition II, the percentage of responding to the light alone was very low while the percent responding to the tones alone was high. The intermediate response percentages of the tone-light compounds demonstrated that the light had become an effective conditioned inhibitor. As in Condition II, the response percentages to the tone-light compounds also showed differential compound stimulus control.

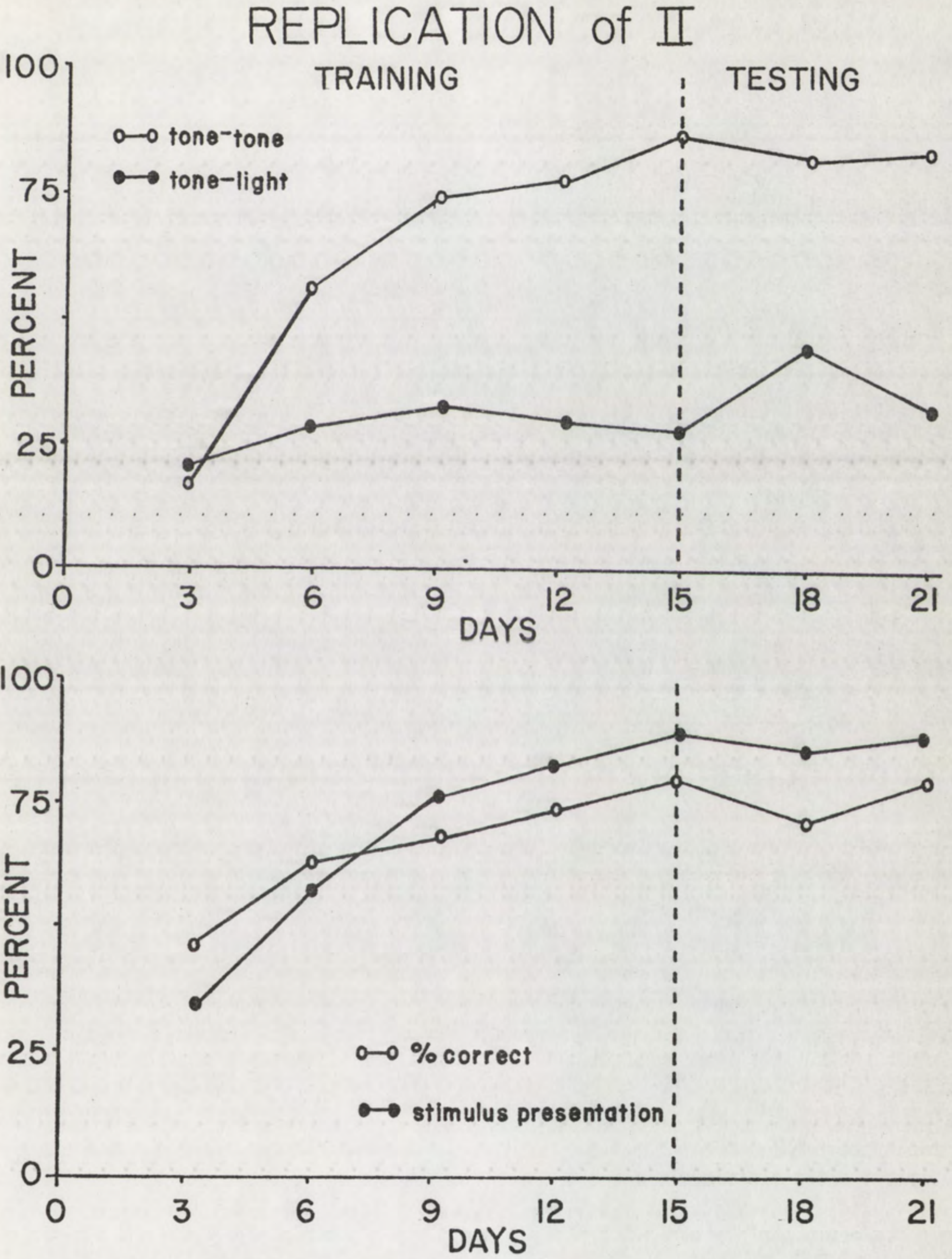

Fig. 11. Percent responding to tone-tone and tone-light compounds (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) across acquisition and testing days.

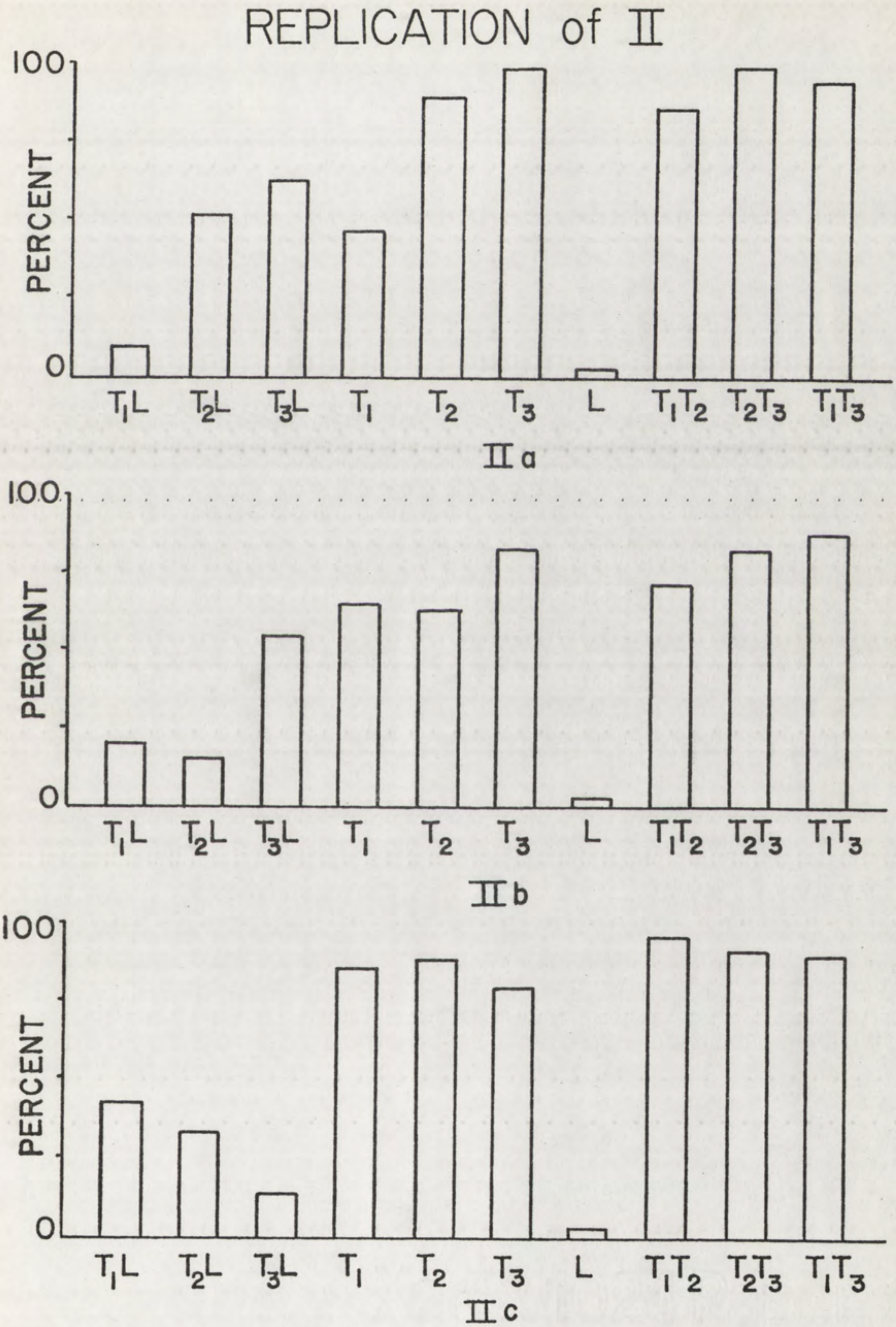

Fig. 12. Mean percent responding to all stimuli during testing in Replications IIa (top), IIb (middle), and IIc (bottom).

For Group I, T_1L was lower than both T_2L and T_3L although all compounds were nonreinforced. T_2L was lower than T_1L and T_3L in Group II, and T_3L was lower than T_1L and T_2L in Group III.

This experiment proved to be a replication of Condition II not only in procedure but also in results. Differential responding due to different reinforcement percentages was obtained in both experiments.

EXTENSION OF CONDITION III

Condition III demonstrated that the discrimination between a tone-tone compound and a tone by itself was a difficult task for the animals. The animals responded only slightly above 50% to the tone-tone compounds. Evidently the rats were not responding as strongly to the cues of differences in intensities between stimuli (two tones psychophysically louder than one tone).

In Conditions I and II, four stimuli were presented to the animals. In Condition III, three stimuli were presented. The trend was toward reduction in the number of stimuli used in order to observe a discrimination between two stimuli differing in reinforcement percentages. It seemed somewhat backward that the progression was from four stimuli to two stimuli. Nonetheless, the reason for using two stimuli in this experiment (corresponds to Condition IV, Table 1, line 9) was because the low asymptotic level of percent correct responding in Condition III indicated that the three stimulus task was a difficult one. Perhaps then, larger differences between a 50% and 75% reinforced cue could be obtained by using only two stimuli (introspectively a simpler task). These two stimuli were in the same modality.

METHOD

Subjects. The same rats used in Condition III were used again. The rats were maintained at 80% of ad lib body weight throughout Condition III and the present experiment. At no time were the animals placed on ad lib diet.

Apparatus. Same apparatus.

Procedure. The animals in each group in Condition III were divided into one of two groups for this experiment. The assignment of which animal to which group was done randomly.

For Condition IIIa, where T_1 was the 50% reinforced cue, the four animals were divided into one of two groups (Groups I and II). One group was presented T_1T_2, T_1, or T_2, and the other group was presented T_1T_3, T_1, or T_3. Thus, the animals of each subgroup were confronted with only two tones. One tone, T_1, was still 50% reinforced, and the other tone (either T_2 or T_3) was 75% reinforced. Again all tone-tone compounds were reinforced while any tone, presented alone, was never reinforced.

Condition IIIb was subdivided into two subgroups also (Groups III and IV). One subgroup of Condition IIIb was presented with either T_1T_2, T_1, or T_2, and the other subgroup was presented with either T_2T_3, T_2, or T_3. Recall that T_2 was the 50% reinforced cue for Condition IIIb. Condition IIIc was similarly subdivided. T_3 was the lower reinforced cue in Condition IIIc. One subgroup received either T_1T_3, T_1, or T_3, and the other subgroup received either T_2T_3, T_2, or T_3.

Two animals were run at one time with the bars being continually grounded in the two operant boxes not being used. Fifty trials a day constituted a session. Twenty-one trials of reinforcement were possible, and 29 trials of nonreinforcement were presented.

The purpose of subdividing the groups in Condition III was to get a further indication of the discrimination being made, if any, between a 75% reinforced cue and a 50% reinforced cue. Rather than using three stimuli, however, only two stimuli were used.

RESULTS AND DISCUSSION

The acquisition data for Condition III and its extension have been combined for comparison purposes in Figure 13. The percentage of responding to the tone-tone compounds remained at a high asymptotic level and appeared to increase slightly over days in the extension. Percent responding to the tones when presented alone appeared to decrease over days. Examination of the bottom graph in Figure 13 shows that the percent correct responding also remained near 50% whereas percent responding done only during the stimulus presentations remained at a high asymptotic level.

The actual percentages of responding to each of the stimuli, both compounded and single stimuli, are shown in Table 12. An analysis of variance testing differences within subjects for a group by reinforcement percentage effect was performed on the data of Table 12. Six groups with two subjects in each group were compared for differences in responding between a 75% reinforced cue and a 50% reinforced cue. First of all, there was a highly significant difference between response percentages of the 75% reinforced cue and the 50% reinforced cue. Response percentages to the 75% reinforced cue were higher than the response percentages of the 50% reinforced cue ($\underline{F}$ (1,6) = 49.278, $\underline{p} < .01$). Secondly, there was a significant difference between groups ($\underline{F}$ (5,6) = 5.883, $\underline{p} < .05$). Groups with either the low tone (T_1, Groups I and II), 50% reinforced, or the high tone (T_3, Groups V and VI), 50% reinforced, showed greater differences in percentages between the 75% reinforced cue and the 50% reinforced cue. This group by treatment interaction also proved significant at the $\underline{p} < .05$ level ($\underline{F}$ (5,6) = 4.50.).

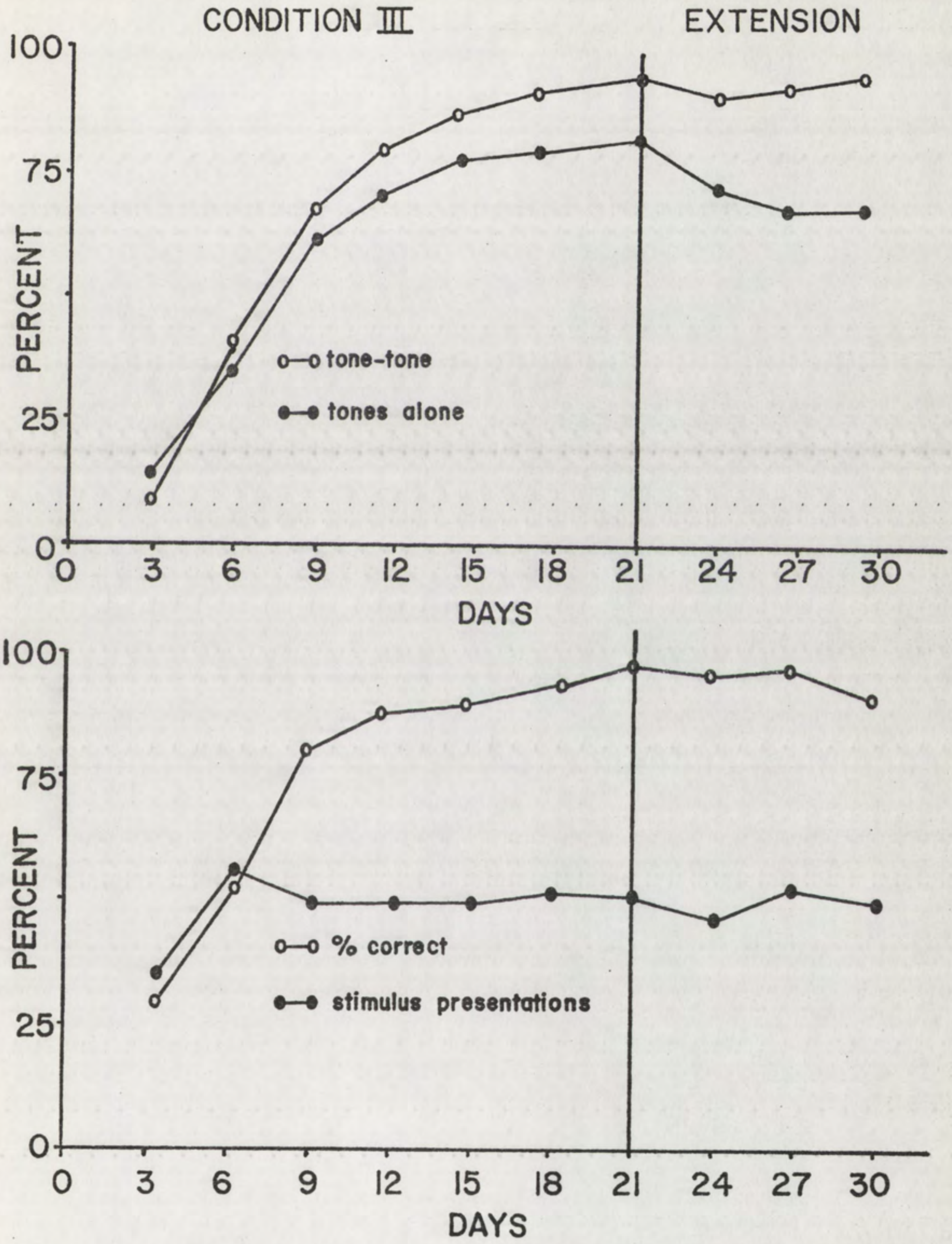

Fig. 13. Percent responding to tone-tone compounds and to tones alone (top graph) and percent correct responding and responding only during stimulus presentations (bottom graph) for Condition III and the Extension of III.

The percentages of responding for each group across days is graphically displayed in Figure 14. The top two graphs show the differences in percent responding to T_1, as the 50% reinforced cue, and T_3 (top left) and T_2 (top right), both 75% reinforced. T_1 in both graphs is lower in percent responding. However, the difference between T_1 and T_3 appears considerably larger than the difference between T_1 and T_2.

The middle graphs show the differences in responding between T_2, 50% reinforced, and T_1 (middle left) and T_3 (middle right), both 75% reinforced. T_2 should show the lowest percentage of responding in both graphs, but in the middle left graph, T_1 is lower than T_2, contrary to what it should be. In the middle right graph, a large difference in the expected direction was obtained between T_2 and T_3.

The bottom left graph shows the differences between T_2 (75% reinforced) and T_3 (50% reinforced). The percent responding to T_3 was lower than that of T_2 as predicted. The bottom right graph shows the differences in response percentages between T_1 (75% reinforced) and T_3 (50% reinforced). Again the differences between two stimuli farthest apart in pitch (T_1 and T_3) were larger than differences obtained for two stimuli nearer in pitch (T_2 and T_3).

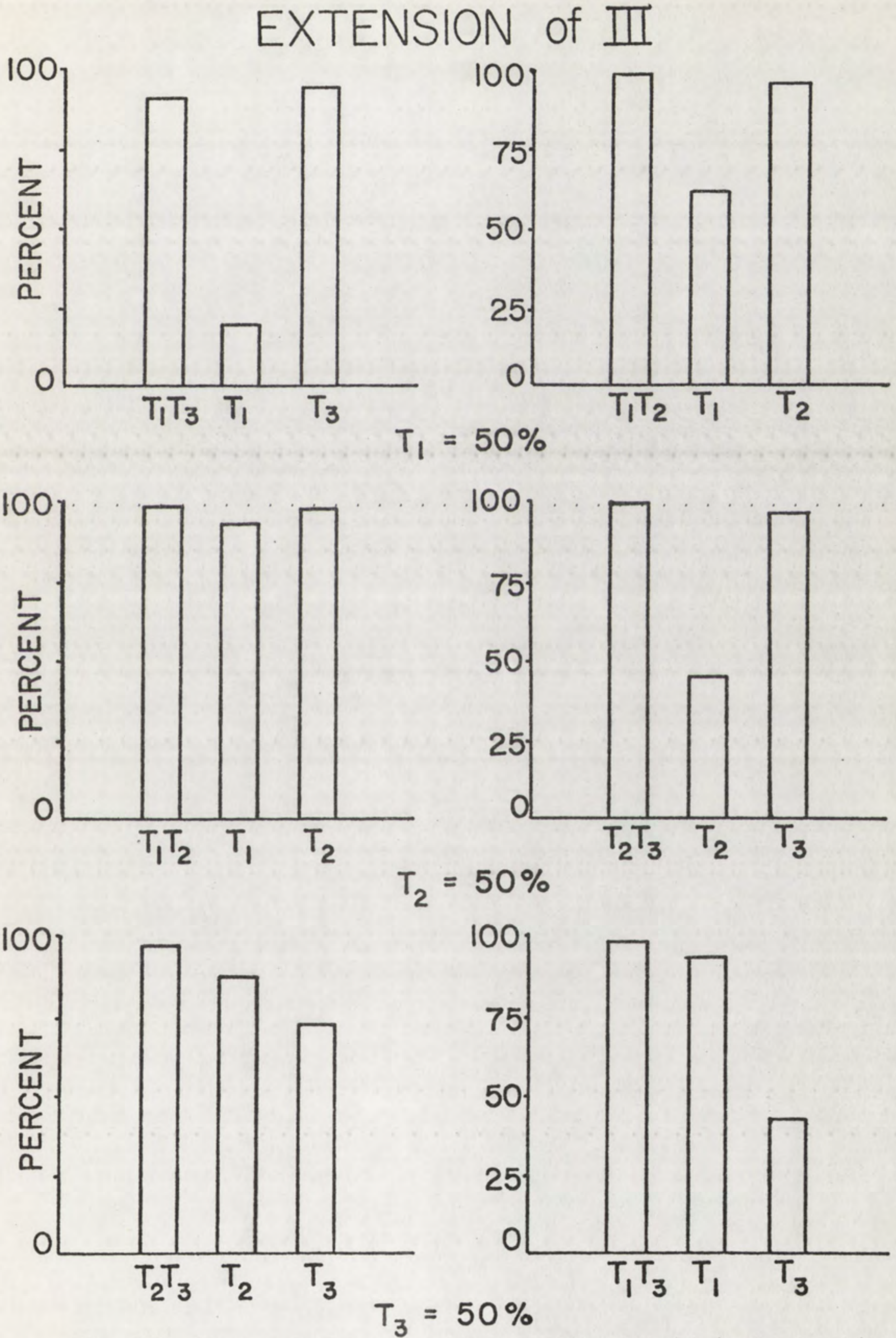

Fig. 14. Mean percent responding to all stimuli during testing in Extensions IIIa (top left), IIIb (top right), IIIc (middle left), IIId (middle right), IIIe (bottom left), and IIIf (bottom right).