4-1980

An Analysis of the Peak S h ift Explanation o f Response Summation

Jeanne Page
Western Michigan University

An Analysis of the Peak Shift Explanation of Response Summation

by

Jeanne Page

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
April, 1980

TABLE OF CONTENTS

INTRODUCTION

When subjects have been trained on two discriminations, the presentation of a compound stimulus consisting of the two S+'s (stimuli in the presence of which a response is reinforced) results in a higher response rate than the presentation of either stimulus alone. This increase in rate is known as response summation (Wolf, 1963; Weiss, 1969; 1971). A three-component multiple schedule is typically used, and the response is extinguished (not reinforced) in the presence of S-, which is both S+'s off. The order of the stimuli in the training schedule is $S+_1$, S-, $S+_2$, S-. In testing, the compound stimulus, consisting of the two S+'s presented simultaneously ($S+_c$), and the two component S+'s are alternated with S- ($S+_1$, S-, $S+_2$, S-, $S+_c$, S-), with response rate in the presence of each recorded. The number of responses to $S+_c$ is usually greater than the number of responses to $S+_1$ or $S+_2$. For example, Wolf (1963) used two lights as training S+'s, and stimulus-off as S-. Presentation of both pairs of lights, lit simultaneously, constituted $S+_c$. His subjects emitted more responses to $S+_c$ than to $S+_1$ or $S+_2$ alone, thus exhibiting response summation to the compound stimulus.

Wolf (1963; unpublished data) and Weiss (1969; 1971) have analyzed response summation in terms of peak shift. When a single discrimination is trained on one dimension and a generalization

test is conducted along that continuum, peak shift describes the displacement of the maximum response rate from S+ in a direction away from S- (e.g., Hanson, 1959). In response summation studies, the compound stimulus, both-on, is considered to be farther from S-, both-off, than either stimulus alone. Hence, more responses occur to the compound stimulus.

Weiss (1969) based that analysis on the assumption that the compound stimulus and its separate components lie on one continuum consisting of total amount-of-stimulation. He stated that the "composite continuum is defined by the on-off states of all relevant S+'s, one continuum extreme anchored to the all-on state, the other to the all-off." In one experiment, he deviated from the typical procedure by using both-on as S-. During training, the condition of both-off was not presented; it was, however, the stimulus compound for the test. Light-on with tone-off, and tone-on with light-off, were the two S+'s, and both-on was the S-. Testing revealed that summation occurred to both-off, the compound stimulus. With the continuum being defined as total amount-of-stimulation, Weiss' results showed that summation occurs when either end of the continuum is used as S-. Hanson (1959) trained with 550 mu as S+ and 590 mu as S-, and Terrace (1964a) trained with 580 mu as S+ and 540 mu as S-. Peak shift was evident in subsequent generalization tests in both studies. With wavelength as the stimulus dimension, these results show that training can

occur with S- on either side of S+, and peak shift will still occur. Weiss interpreted his own results as support for his peak shift analysis, because they demonstrated a functional similarity of the presence-absence continuum to the wavelength continuum.

Wolf (unpublished data) found that without an extinction component in training, summation did not occur. He eliminated the extinction component during training, and reinforced responding in the presence of each of three stimuli, using the same schedule of reinforcement for each stimulus. The stimuli were sections of a response key, vertically divided in three parts. The middle section was white, the right was red, and the left was green. When two of those stimuli were presented simultaneously, the resultant response rate was lower than the rate to either stimulus alone. Thus, maximum stimulus control was exerted by the S+, as is the case with stimulus generalization studies with no extinction during pre-training (Guttman and Kalish, 1956). Since S- training is necessary for peak shift to occur, this finding could also be taken as support for the peak shift analysis.

In this same study, Wolf attempted to show that stimulus intensity was not the dimension responsible for the occurrence of peak shift. In the above studies involving stimuli-off as S-, the sequence S-, S+, S_c, was correlated with both intensity and the total spacial area of stimulation provided by the visual stimuli. Both of these dimensions might contribute to the "amount-of-stimulation" dimension. The least amount-of-stimulation corresponded to a zero intensity and zero area (all stimuli off, S-),

an intermediate amount-of-stimulation corresponded to an intermediate intensity and a medium area of stimulation (one S+ on), and the most amount-of-stimulation corresponded to a high intensity and a large area of stimulation (both stimuli on, S_c). He used one response key vertically divided into three sections, still using a three-component multiple schedule. The stimuli were those described above; the middle section of the key was white and correlated with extinction; the right side was red and the left was green, each correlated with a variable interval (VI) 60 sec schedule (the temporal value denoted to the reinforcement schedule, i.e., 60 sec, is the mean amount of time that must pass before a response can yield reinforcement). Simultaneous illumination of both side sections of the key, red plus green, constituted the compound stimulus for the summation test. The S- intensity in this experiment was greater than each S+ intensity, and also greater than the intensity of the compound stimulus, $S+_c$. So, the order of stimuli from the lowest to the highest intensity, was green, red, green plus red, and white. Wolf was controlling for the possibility that summation was due only to the increased intensity of the compound stimulus over that of either training stimulus alone. Summation occurring to $S+_c$, which fell between one of the S+'s and S- on the intensity continuum, could not be due to peak shift along that continuum. The responding of all three subjects showed summation in the test. Thus, the results indicated that if peak shift occurred, intensity was not the continuum involved in the peak shift. Although Wolf did not discuss it, he also eliminated the area of stimulation as the dimension over

which peak shift might have occurred since the area of the S- was about equal to that of each S+. Nevertheless, Wolf still described the results in terms of peak shift. Wolf defines the continuum in his study as including S_c, both S+'s, and S-, where "combined (S+'s) represent a point on the (S+-S-) continuum more distant from the (S-) than either of the original (S+'s)." Wolf's continuum is then defined in terms of stimulus functions (i.e., S_c, $S+_1$, $S+_2$, and S-). "The present procedure, involving an arbitrary composite stimulus dimension, is functionally equivalent to the (generalization) procedures (showing peak shift) involving unitary stimulus dimensions" (Wolf, 1963). Evidence that these stimuli form a continuum is given by not only the experiment discussed immediately above (which presumably showed that peak shift along the intensity continuum could not account for the results) but by the fact that response summation occurs following discrimination training but not after training which omits the S-. This makes the S+-S- "continuum" appear functionally equivalent to a unitary continuum. Whether or not this sort of analysis should be accepted should probably be determined by additional independent demonstrations of the functional equivalence of the S+-S- continuum to a unitary continuum.

A problem arises in this study by Wolf (unpublished) from the use of a visual S- at a location separate from but bordered by the locations of the two visual S+'s. White on the center of the key was used as S-, and red on the right and green on the left were used as S+'s in training. The subject may learn only one discrimination, i.e., presence versus absence of S-. Thus, responding could

have occurred to the absence of white, and not the presence of either S+. Whenever light borders dark, the dark seems darker than when dark is adjacent to more dark. This psychophysical phenomenon is known as brightness contrast. The compound stimulus may yield more responses than either S+ alone because, due to brightness contrast, the middle section of the key appeared darker when both side sections were lit than when either side section was lit alone. Response rate may increase in the presence of the compound stimulus because of the more pronounced absence of S-, in which case, the amount-of-stimulation continuum could be said to control responding, in support of the peak shift analysis. Another possibility is that the center section of the key had no control over the animals' responding. Correct responding could have been based on the side sections of the key only, and not the center section. Thus, the functional S+'s may have been left or right side of key on and the S- may have been both-off. Therefore, this analysis also indicates that the amount-of-stimulation continuum could still be the basis for a peak shift.

In order to eliminate these problems, the present study involved training two discriminations on different visual stimulus dimensions, where the S+'s and S-'s occurred at the same location. Training stimuli were red versus green and vertical versus horizontal lines. Peak shift was expected along wavelength and line angle dimensions individually; but since no on-off training was possible, no peak shift was expected along the amount-of-stimulation continuum. Thus, if summation were to occur in this study, it would not

be a matter of peak shift along the amount-of-stimulation continuum.

The present study was a replication of Wolf's (unpublished data) experiment with some modifications. Wolf trained pigeons on a three-component multiple schedule, where the reinforcement schedule associated with the components was either extinction or VI. He varied the final VI value between subjects in Experiment 1, but in Experiments 2 and 3 used VI60 sec only. The sequence of the training stimuli was green (S+), white (S-), red (S+), white (S-), and this order was constant throughout training. Once the discrimination was trained, a test was conducted in extinction. The test was composed of four stimulus conditions: green, red, red plus green, and white. The order of the stimulus presentations was quasi-random during testing; each training S+ was preceded by the corresponding training S- from a given dimension, and the compound S+ always followed the compound S-. The order of stimulus pairs was randomized in blocks of three successive stimulus pairs, each pair presented once per block. No S+ condition could follow itself when presentation of the stimuli began again. In the present study, S+'s were red and a vertical line for each of two groups. For the control group, S- was stimulus-off; this group was a replication of Wolf's procedure with minor modifications. For the experimental group, S-'s were green and horizontal. For this group, rather than one S- (stimulus-off) alternating with both S+'s in training, two S-'s were used in training, one from each continuum. The major procedural difficulty was determining how to present the S-'s to best equate the procedure with Wolf's, and with the procedure for

the control group of the present study, both in training and in testing. In training, Wolf's S- could be said to be from the same dimension as both of his S+'s. Therefore, one could say that his S+'s were preceded and succeeded by intradimensional S- stimuli. Because of the difference in S-'s, this was impossible in the present study without presenting twice as many extinction components as Wolf did (e.g., $S-_1$, $S+_1$, $S-_1$, $S-_2$, $S+_2$, $S-_2$). The sequence of stimuli in the present study consisted of pairs of intradimensional stimuli, with S- preceding S+ (e.g., $S-_1$, $S+_1$, $S-_2$, $S+_2$). In testing, where Wolf randomized the order of the S+'s and $S+_c$, and alternated each S+ and $S+_c$ with an S- component, pairs of stimuli (S-, S+) from each dimension were randomized in the present study. The compound of the two S-'s preceded $S+_c$.

Method

Subjects

The subjects were seven barren-hen White-Carneaux pigeons of unknown age, housed in individual cages. They were maintained between 70 and 80 percent of their free-feeding weights with mixed Purina pigeon grains, which also was used as a reinforcer. Six of the subjects, S1, S2, S3, S4, S5, and S6, were experimentally naive; one subject, S7, had an experimental history consisting in one case of a simple color discrimination between red and green, and in another case of a "people" discrimination in which pecking a stimulus cube was reinforced when the stimulus cube had a picture of a person on it, and was not reinforced when the cube had a picture of objects with no people on it. Both discriminations were established in a modified Wisconsin General Testing Apparatus (Millar and Malott, 1968). Grit and water were available at all times in the home cages. Assignments to test chambers were as follows: S1, S2, and S3 in Chambers 1, 2, and 3, respectively; S4 and S6 in Chamber 1, and S5 and S7 in Chamber 2.

Apparatus

Three identical standard two-key Lehigh Valley Electronics pigeon testing chambers were used. The distance between the center of the response keys and the floor of the chamber was 23 cm. The keys were located 8.8 cm from the left and right edges of the intelligence panel. Each key was 2.5 cm in diameter and made of

translucent plastic. The left key only was used. Stimuli were projected on the keys from the rear using one-plane readout stimulus projectors (Industrial Electronics Inc.). Centered on the intelligence panel, 11 cm above the floor, was a 5 cm by 6 cm opening for the delivery of grain. The houselight, a General Electric 1815 (12.5 v) bulb, was centered on the intelligence panel, 25.5 cm from the floor of the chamber. A model 1C939 fan from Dayton Electric Mfg Co. provided a low level of masking noise as well as ventillation, and was located on the outside of the chamber. Scheduling of experimental events and data collection were accomplished with software from State Systems Inc., Kalamazoo, Mich., and a PDP8-L computer from Digital Electronics Corp., located in an adjacent room. Papertape Super SKED was used for programming.

Procedure

The subjects were trained to eat food out of the food magazine when operated, and manually shaped to peck a yellow response key by standard operant conditioning procedures (Skinner, 1958). After delivering twenty reinforcers (three seconds access to grain) on a continuous reinforcement (CRF) schedule where every key peck response was reinforced, the stimulus was changed to a red response key. Twenty reinforcers were then delivered on a CRF schedule for pecking the red response key. Following this the stimulus was changed to a white vertical line on a dark background for all subjects, and again, each subject received twenty reinforcers on a CRF schedule for pecking the response key. After 10 hours of ex-

posure to the vertical line, S7 was still not pecking the key. Five non-contingent reinforcers were then presented to this subject in the presence of the vertical line. The subject did not approach the hopper. The vertical stimulus was then changed to a white horizontal line on a dark background for S7 only. As with the other subjects in the presence of the vertical line, twenty reinforcers were delivered to S7 on a CRF schedule for pecking the response key with a horizontal line on a dark background. Sessions involving CRF were terminated after twenty reinforcers had been delivered in the presence of one stimulus, or two hours had elapsed, whichever occurred first.

Multiple schedule training was then instituted. The order of the stimuli was constant during training. It was: vertical line, horizontal line, red, and green for S1, S2, and S3; vertical line, stimulus-off, red, and stimulus-off for S4, S5, and S6; horizontal line, stimulus-off, red, and stimulus-off for S7, as shown in Table 1. Responding in the presence of the first and third stimuli (S+'s) in the sequence was reinforced. Responding in the presence of the second and fourth stimuli (S-'s) went unreinforced. During the initial 10 hours of exposure to the multiple schedule, a VI20 sec schedule of reinforcement was in effect; that is, every response in the presence of an S+ occurring after an average of 20 sec had elapsed since termination of the previous reinforcement delivery, yielded reinforcement. The schedule was then changed to VI60 sec, which was in effect for the remaining 20 hours of training. When an S+ condition was terminated and an

Table 1

Assignment of subjects to the different stimulus conditions

Subject	S+	S-	S+	S-	Positive Compound	Negative Compound
1, 2, 3	vertical	horizontal	red	green	vertical red	horizontal green
4, 5, 6	vertical	off	red	off	vertical red	off
7	horizontal	off	red	off	horizontal red	off

S- condition began, the VI timer was re-set, so that a new interval began. The interval lengths for both VI20 sec and VI60 sec schedules were computed from the progression suggested by Fleshler and Hoffman (1962). Each stimulus presentation lasted five minutes. The sequence of stimulus presentations, indicated above, was repeated until the session was terminated. Sessions of VI20 sec training were 60 min in length, VI60 sec sessions were two hours long. Sessions were generally conducted seven days per week; but for S4 and S7, there was a four day lapse between the VI20 sec and VI60 sec training. Due to an apparatus malfunction, S3, S5, and S6 were exposed to the red (positive) stimulus for 45 min in extinction during the third training session on VI60 sec. The response rates and a minimum of 90% accuracy in discrimination performance were recovered after two more sessions of normal VI60 sec training for all three subjects.

The final session of the study was a summation test conducted in extinction. The stimuli for the test consisted of those stimuli used in training, as well as compound stimuli. The positive compound was composed of the line angle that served as S+ in training sessions, superimposed on the color that served as S+ in training sessions, as indicated in Table 1. The negative compound was composed of the two S-'s, a horizontal line on a green Key, for S1, S2, and S3. For the remaining subjects, the negative test stimulus was a dark key. The order of stimulus presentations was quasi-random during testing; each training S+ was preceded by the corresponding training S- from a given dimension, and the compound

S+ always followed the compound S-. So three pairs of stimuli (line angle, color, and compound stimuli) were presented during the test. The order of stimulus pairs was randomized in blocks of three successive stimulus pairs, each pair presented once per block. Each stimulus presentation was 60 sec in length, with the test session lasting one hour. Number of responses in the presence of each stimulus condition was recorded throughout the study. The houselight and white noise were on at all times.

By the final training session, S1, S2, S4, S5, and S6 were emitting between 1100 and 1500 responses in the presence of each of the two S+'s in a single session. The exceptions were S3 and S7: S7 emitted at least 2500 responses in the presence of each S+; S3 emitted between 800 and 1000 responses in the presence of each S+. The color and line angle discriminations of all subjects but S3 were at or better than 90% accuracy at the termination of training. The responding of S3 recovered to a minimum of 90% accuracy after exposure to extinction in the presence of red; thereafter, the line angle discrimination was maintained at or above 90% accuracy, but after four hours of discrimination training, the color discrimination fell to 85%. There was no consistent difference between groups in terms of the degree of the discrimination, and the terminal response rates in the presence of S+.

RESULTS

Figures 1 through 7 show the cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S1, S2, S3, S4, S5, and S6, and red, horizontal, and red plus horizontal for S7. The data show that summation does not occur with the stimuli used in this study.

With five of the seven subjects (S1, S2, S3, S4, and S7), the total number of responses emitted in the presence of the compound was less than that in the presence of either training S+. The three subjects trained with green and horizontal as the two S-'s (S1, S2, and S3) clearly emitted fewer responses to the compound stimulus than to either S+ alone, as shown in Figs. 1, 2, and 3. Those subjects also ceased responding to the compound stimulus before they stopped responding to the S+'s. The total number of responses emitted by S3 during the test was less than half the number emitted by any subject not exposed to extinction during training. Figure 7 shows that S7 showed a pattern of responding similar to those of S1, S2, and S3, although S7 had stimulus-off as S-, as did S4, S5, and S6. Figure 4 shows that S4, trained with stimulus-off as S-, responded in a manner similar to S1, S2, S3, and S7, in that a decrease in the number of responses to the compound stimulus was evident at the termination of the test, and responses were still being emitted in the presence of the S+'s. However, until the ninth block of stimulus presentations, the number of responses to the compound stimulus

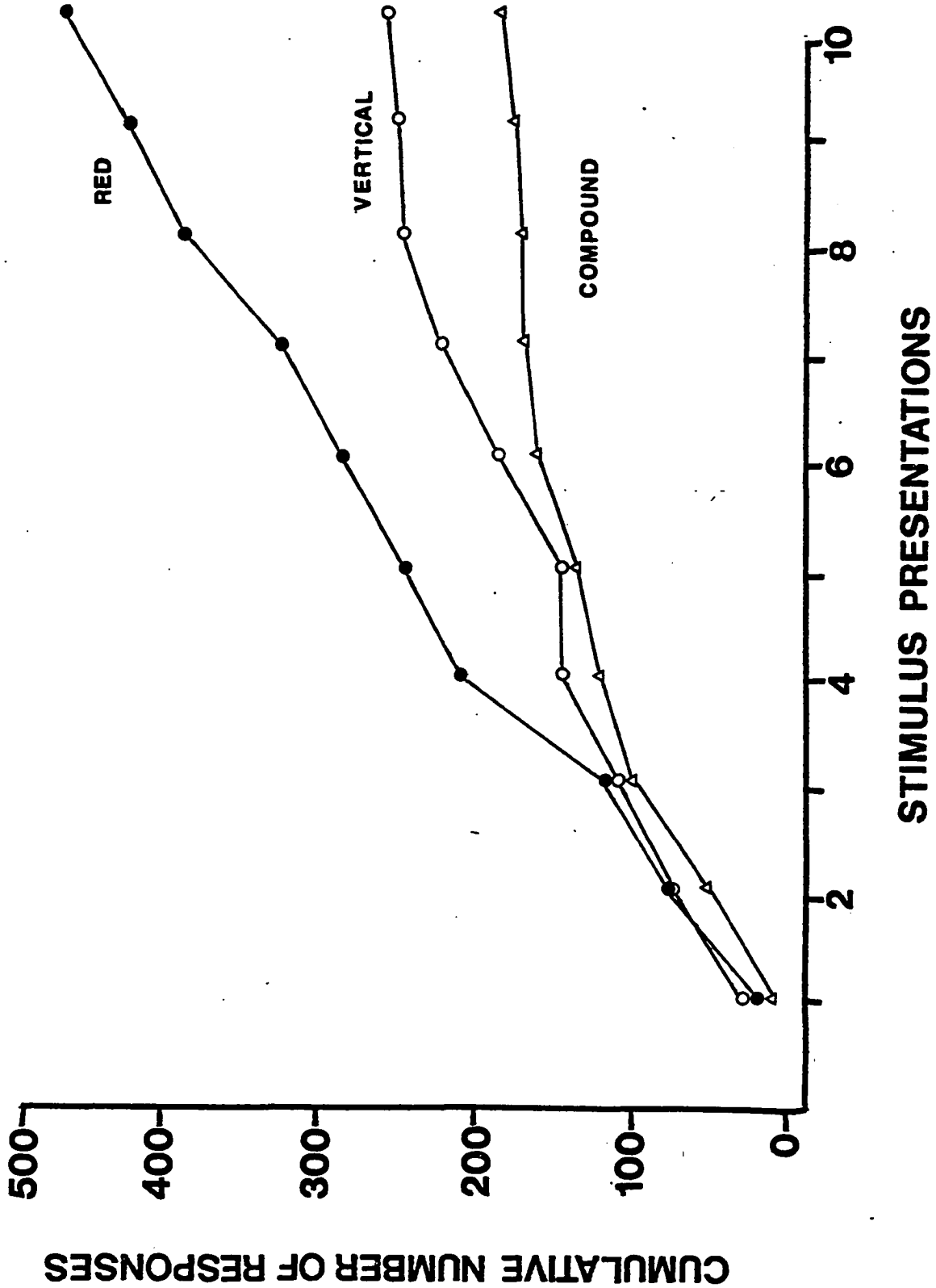

Figure 1

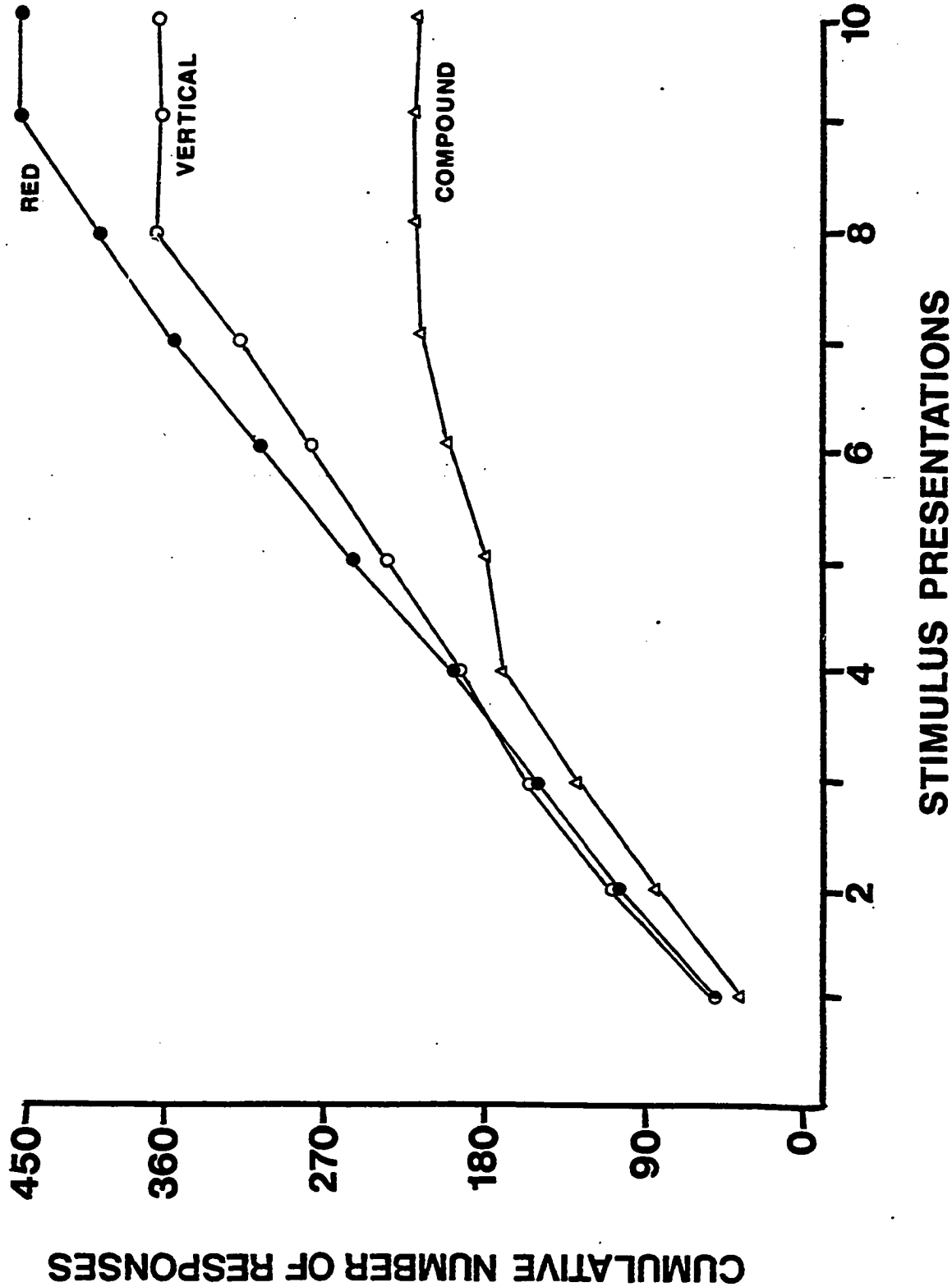

Figure 2

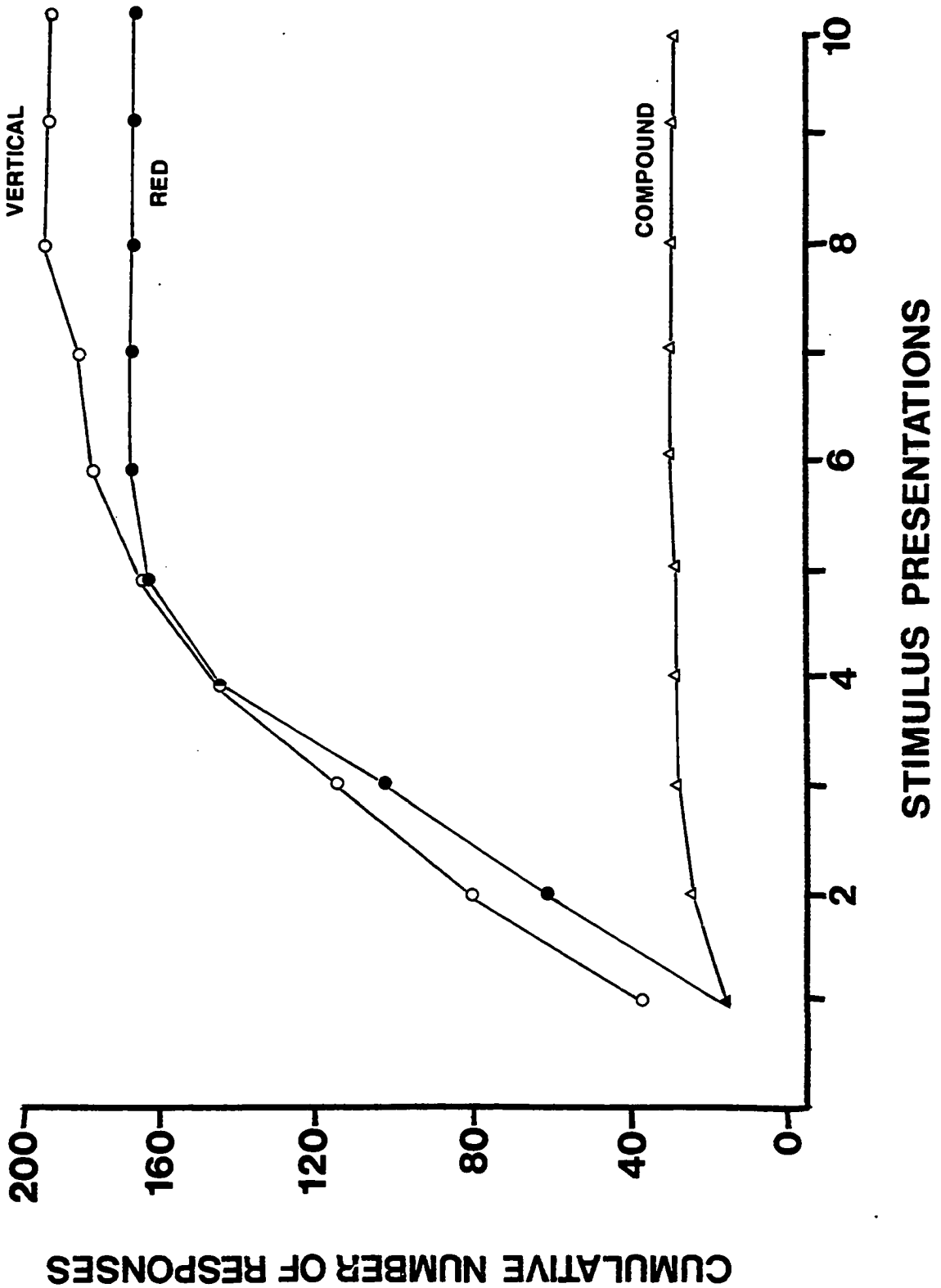

Figure 3

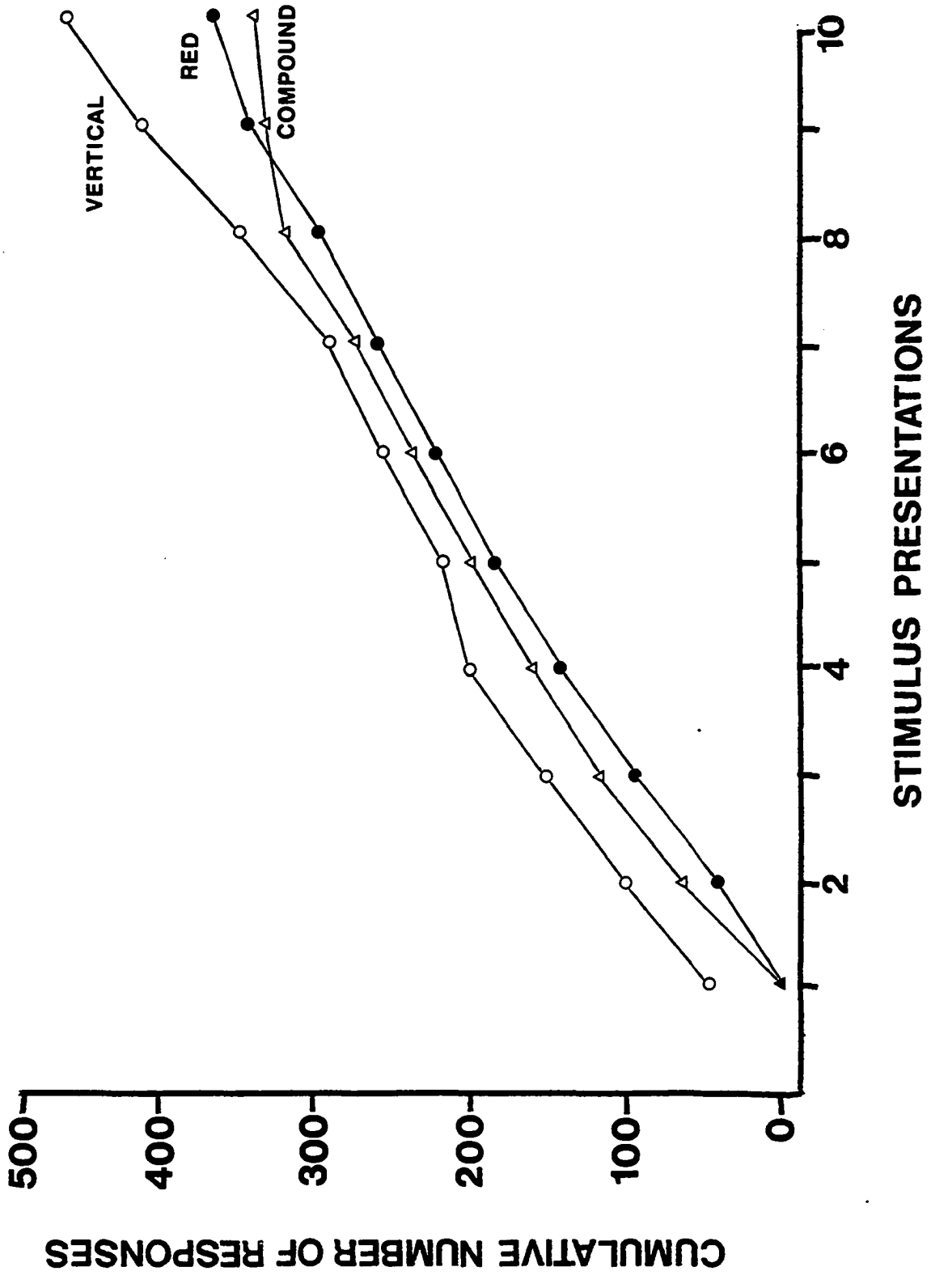

Figure 4

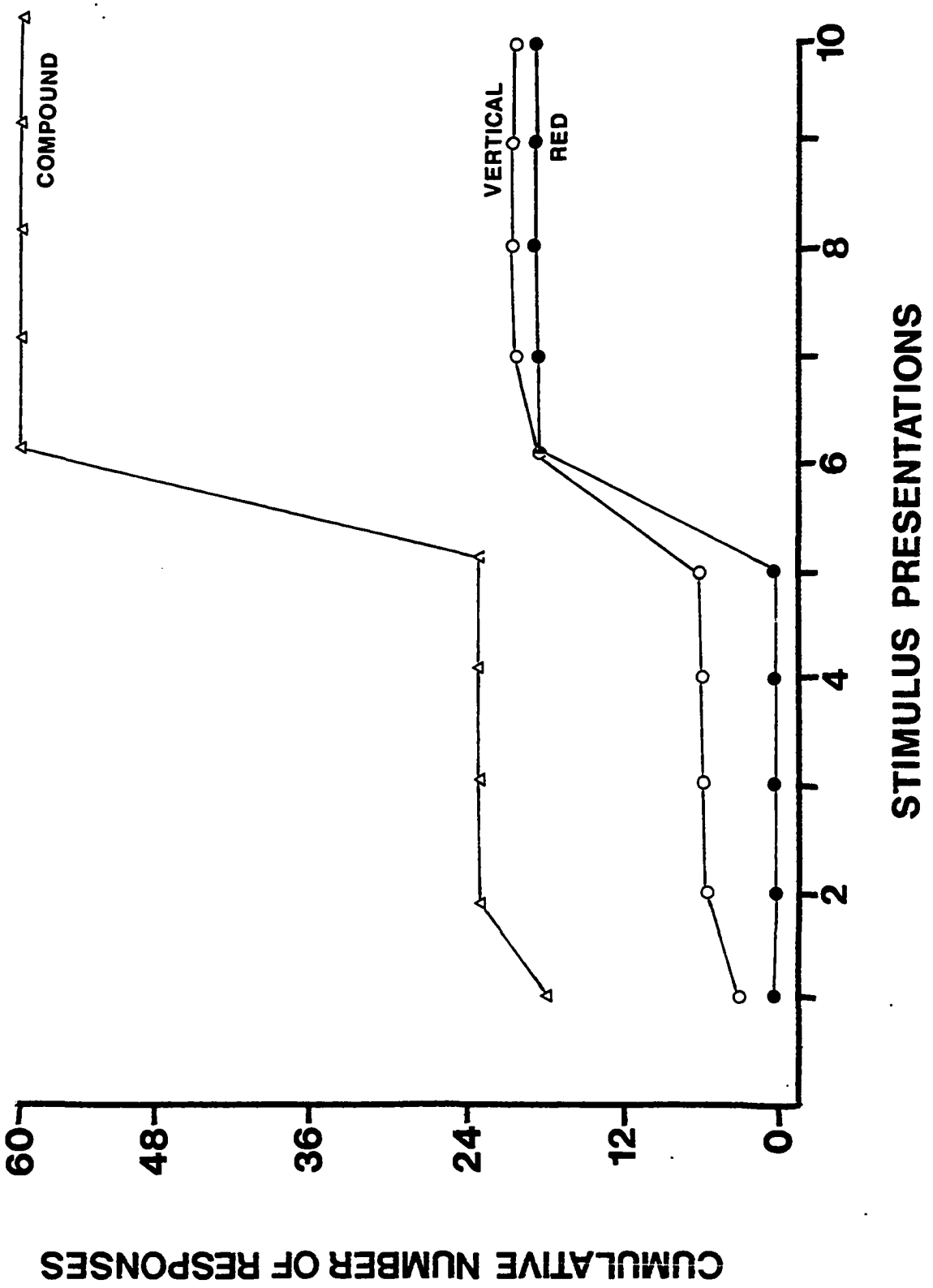

Figure 5

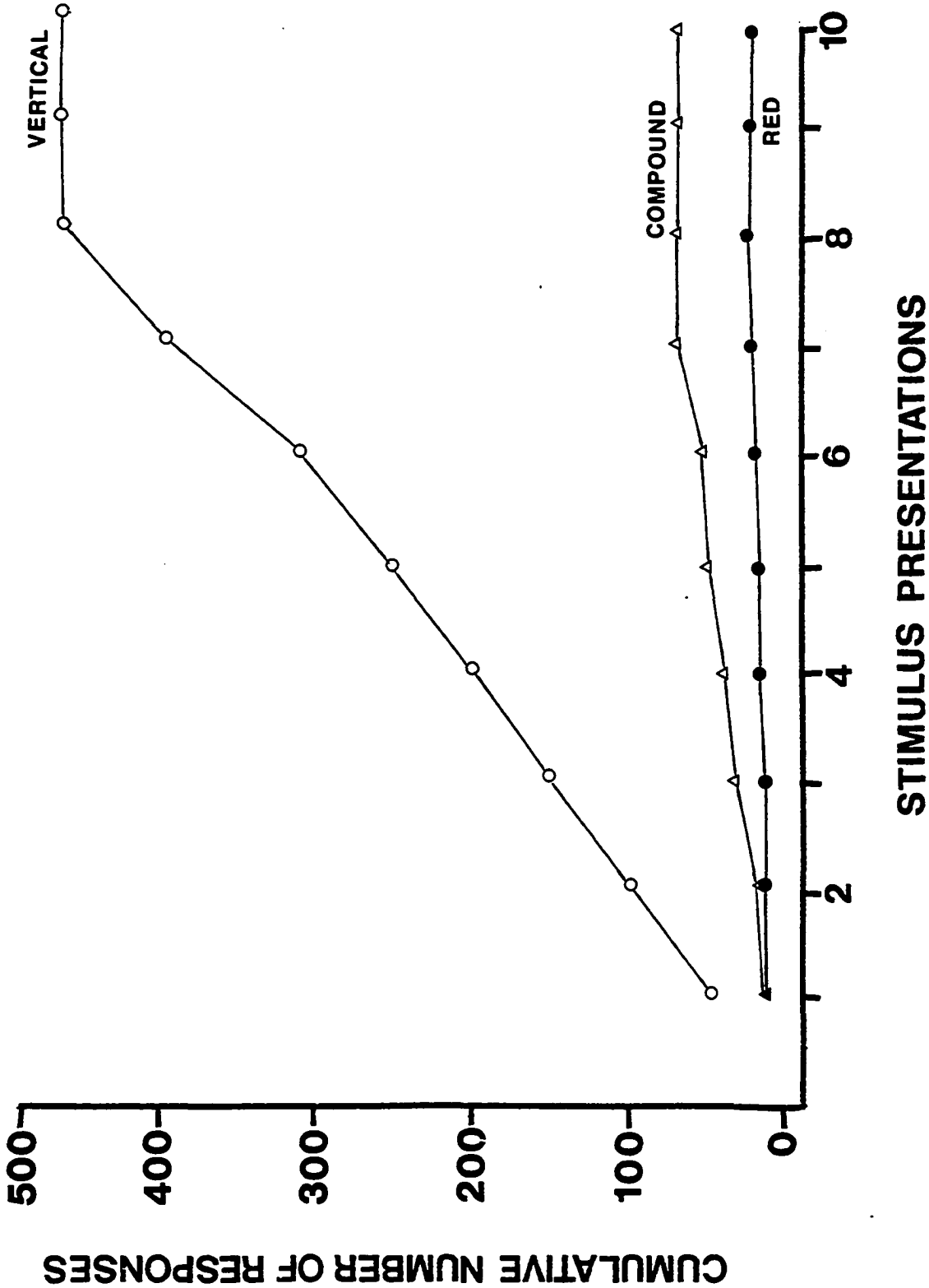

Figure 6

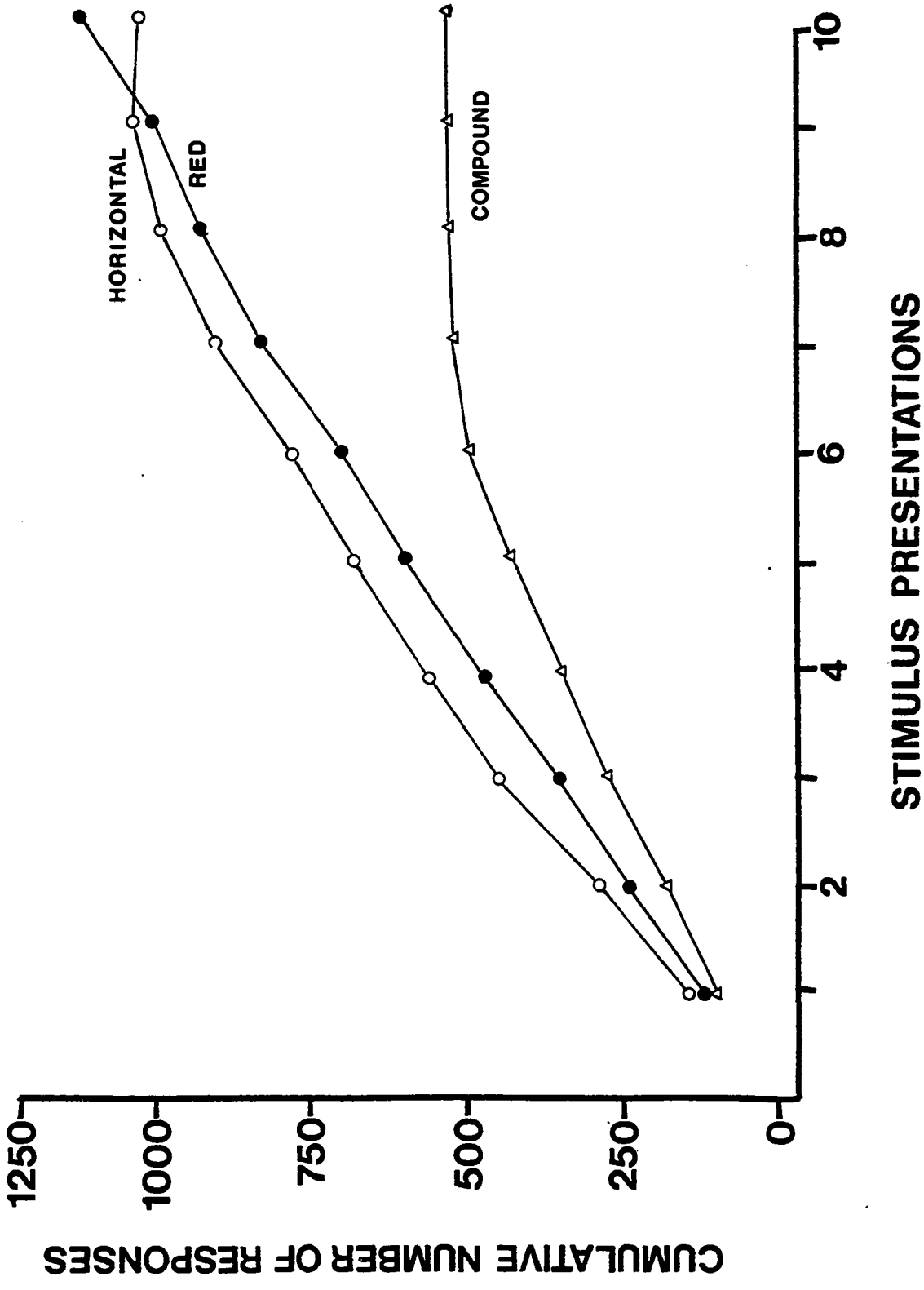

Figure 7

was between that to red and that to vertical, making the pattern of responding earlier in the test different from the responding of S1, S2, S3, and S7. The responding of S5 summated, but that bird only responded on nine of the 60 test trials, and emitted less than 25% of the total number of responses of any other subject. For S6, ten times as many responses were emitted in the presence of the vertical line as in the presence of either red or red plus vertical. The lowest number of responses was emitted in the presence of red, the positive stimulus in the presence of which responding had been extinguished.

In the test, the three subjects with green and horizontal as S-'s (S1, S2, and S3) consistently showed the opposite of response summation. The four subjects with stimulus-off as S- (S4, S5, S6, and S7) responded inconsistently in the test, with S4 and S7 emitting the least total number of responses to the compound, S6 an intermediate number of responses to the compound, and S5 emitting more responses to the compound than to either S+ alone. The data show that neither differences in the terminal response rates in training nor the total number of responses in the test seem to provide an explanation for the differences between subjects.

The low number of responses that S6 emitted both to the compound stimulus and the red S+ may have been due to the prior extinction in red and the similarity of the compound to red. This, as well as the lack of overall responding from S5 in the test, the low number of responses emitted by S3 in the test, and the difficulty in maintaining a red versus green discrimination for S3 in

training, indicates that the extinction session probably had a detrimental effect on the performance of those three subjects. However, it does not seem to explain any consistent differences between subjects. Three subjects, S1, S2, and S7, emitted more total responses in the presence of color than line angle; S3, S4, S5, and S6 responded more to line angle than to color. Although S3, S5, and S6 had been exposed to red in extinction, S4 had not; it is therefore difficult to draw a strong conclusion that extinction in red reduced the tendency to respond to red in the test.

DISCUSSION

Summation did not occur in either group in the present study. Not only did the experimental group (those subjects trained with green and horizontal as S-'s) fail to show response summation in the test, the control group (an attempt to replicate Wolf's (unpublished data) study using stimulus-off as S-) also failed to show summation in the test. The explanation for the discrepancy with prior studies may be found in the fact that both training S+'s were changed in the present study when the compound stimulus was presented. Traditionally, two separate S+'s have been presented in different locations during training; either a right stimulus light has been $S+_1$ and the left has been $S+_2$, or a single stimulus light has been $S+_1$ and an auditory stimulus $S+_2$. When the compound stimulus has been presented, the two were presented simultaneously and neither stimlus interfered with the other.

In the present study, however, the S+'s had overlapping locations. In the test, $S+_1$ (a vertical or horizontal line) was superimposed on $S+_2$ (a red key) to form the compound stimlus, thereby changing each training S+. The white line was no longer on a dark background, and the red key was divided by a white line. For summation to occur, it may be necessary for the compound stimulus to be composed of stimuli which do not interfere with each other. When a training S+ is altered, a decrease in response rate results (a stimulus change decrement). Generalization gradients frequently

illustrate this effect (e.g., Guttman and Kalish, 1956). This stimulus change decrement could explain the lack of summation in the present study, affecting the results of both groups.

However, the experimental group consistently showed a lack of summation, and the control group's results were inconsistent. It may be that the control group would show summation if this were not counteracted by a stimulus change decrement. If such a difference between groups occurred, as the present experiment (somewhat weakly) implies, this would support the notion that summation occurs only when a peak shift along the amount-of-stimulation continuum is involved. An experiment could be performed identical to the present one except that in the experimental group the two discriminations would be between two tones of different frequencies and between two colors. This would both eliminate the possibility of peak shift along the amount-of-stimulation continuum (the original intent of the present experiment) and the problem of stimulus interference producing a stimulus change decrement during testing with the compound S+.

REFERENCES

Blough, D. S. The study of animal sensory processes by operant methods. In Honig, W. K. (Ed.), Operant Behavior. New York: Appleton-Century-Crofts, 1966.

Fleshler, M., and Hoffman, H. S. A progression for generating variable-interval schedules. Journal of the Experimental Analysis of Behavior, 1962, 5, 529-530.

Guttman, N., and Kalish, H. I. Discriminability and stimulus generalization. Journal of Experimental Psychology, 1956, 51, 79-88.

Hanson, H. M. Effects of discrimination training on stimulus generalization. Journal of Experimental Psychology, 1959, 58, 321-334.

Jenkens, H. M., and Harison, R. H. Effects of discrimination training on auditory generalization. Journal of Experimental Psychology, 1960, 59, 246-253.

Millar, R. D., and Malott, R. W. An inexpensive discrimination apparatus for classroom use with pigeons. Psychological Record, 1968, 18, 369-372.

Skinner, B. F. Science and Human Behavior. New York: Macmillan, 1953, 63-64.

Terrace, H. S. Wavelength generalization after discrimination learning with and without errors. Science, 1964, 144, 78-80.

Weiss, S. J. Attentional processes along a composite stimulus continuum during free-operant summation. Journal of Experimental Psychology, 1969, 82, 22-27.

Weiss, S. J. Discrimination training and stimulus compounding: consideration of non-reinforcement and response differentiation consequences of S^{DELTA}. Journal of the Experimental Analysis of Behavior, 1971, 15, 387-402.

Wolf, M. M. Some parameters involved in combined stimulus control. Unpublished doctoral dissertation, Arizona State University, 1962.

Wolf, M. M. Some effects of combined S^{D}s. Journal of the Experimental Analysis of Behavior, 1963, 6, 343-347.

FIGURE CAPTIONS

Figure 1. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S1.

Figure 2. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S2.

Figure 3. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S3.

Figure 4. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S4.

Figure 5. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S5.

Figure 6. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, vertical, and red plus vertical, for S6.

Figure 7. Cumulative number of responses during the summation test in extinction as a function of successive presentations of each of the three positive stimulus conditions, red, horizontal, and red plus horizontal, for S7.