*DISCRIMINATION TRAINING AND STIMULUS
COMPOUNDING: CONSIDERATION OF
NON-REINFORCEMENT AND RESPONSE
DIFFERENTIATION CONSEQUENCES OF S^{A1}*

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In Exp. 1, four rats were trained on a two-component multiple schedule with tone and light each associated with different variable-interval schedules. Extinction in light-out no-tone, common to previous studies reporting additive summation to compounded discriminative stimuli, was omitted from training. In testing, the simultaneous presentation of tone and light controlled a response rate intermediate between that controlled by these stimuli presented singly. In Exp. 2, animals were trained on three-ply multiple schedules. While tone and light were each associated with variable-interval schedules for both groups, light-out no-tone signalled extinction for one and differential-reinforcement-of-behavior-other-than-bar-pressing for the other. This permitted response reduction during light-out no-tone to be viewed independently of non-reinforcement. Responding of both groups showed summation to tone plus light in testing, with the effect clearly larger for extinction-trained subjects. These experiments indicate that: (1) discrimination training afforded by extinction has been integral to additive summation previously reported, (2) response differentiation and non-reinforcement consequences of extinction training contribute to the magnitude of summation, and (3) summation and peak shift might be functionally related phenomena.

Additive summation is a relatively well established behavioral phenomenon in both classical and free-operant conditioning. When several conditioned stimuli (CSs) or discriminative stimuli (S^Ds) independently control a particular response, the simultaneous presentation of these CSs or S^Ds usually leads to a greater response than either presented alone. The classical and free-operant training procedures preceding the stimulus compounding tests yielding additive summation have had many elements in common.

Those free-operant studies reporting additive summation have all employed essentially similar three-component multiple schedule training formats. (Wolf, 1963; Weiss, 1964, 1968, 1969; Cornell and Strub, 1965; Miller and Ackley, 1970; and Emurian and Weiss, 1970.) Responding was maintained by reinforcement in the presence of either of two

S^Ds, tone or light customarily, and was reduced or eliminated through non-reinforcement when these stimuli, light and tone, were both absent.

Extinction training in the simultaneous absence of the several CSs, although not explicit as in the free-operant studies cited above, is an implicit component of those studies reporting additive summation within a classical conditioning paradigm. Pavlov (1927, p. 115) reported that only after considerable training did responses to the environment in general, *i.e.*, in the absence of CSs, drop out. Therefore, extinction in the simultaneous absence of the S^Ds or CSs has been an integral part of those training procedures preceding the demonstration of additive summation to compounded stimuli in both free-operant and classical conditioning.

Experiment 1 removed the non-reinforcement (S^A) component from the three-ply multiple training schedules of the type employed in previous free-operant experiments reporting additive summation, and measured the effects of this manipulation on the distribution of responses to single and simultaneous stimulus presentations during a compounding test. Specifically, animals were trained on a two-ply multiple schedule where tone and light each signalled a different variable-interval (VI)

¹This research was supported by Grant MH-16853 from the National Institute of Mental Health, United States Public Health Service. The author would like to acknowledge his appreciation to Mr. Henry H. Emurian for his assistance in conducting Exp. 1 and 2, and to Mrs. Susan Levine and Mrs. Maureen Christian for their help in running Exp. 2. Reprints may be obtained from the author, Department of Psychology, The American University, Washington, D.C. 20016.

schedule. If the behavioral effects of extinction in the absence of tone-and-light have been integral to additive summation in previous studies, additive summation should not occur with compounded S^Ds (tone-plus-light) in the present experiment.

EXPERIMENT I: EFFECTS OF S^A TRAINING IN STIMULUS COMPOUNDING

METHOD

Subjects

Four naive adult male hooded rats, approximately 340 g at the start of deprivation, were trained and tested at 80 to 85% of their free-feeding weights. Water was available in individual home cages continuously, and each subject was fed the supplemental food ration necessary to maintain its prescribed weight directly after each training session.

Apparatus

The operant training chamber measured 203 mm (8 in.) high, 212 mm (8-3/8 in.) long and 178 mm (7 in.) wide. Its side walls were white translucent plastic and its floor and ceiling were hardware cloth. A microswitch manipulandum and food trough were mounted on the aluminum front wall. The tone employed in training and testing was 2000 Hz (2000 cps) at 90 to 95 db, and the ambient noise level, with the exhaust fan running, was 80 db. The light S^D, generated by a 25-w 120 v-bulb, was 130.2 cd/m² (38 foot-candles). A dim house-light was on continuously. Apparatus and stimuli are described in greater detail elsewhere (Weiss, 1969, 1970).

Solid-state scheduling equipment was located in a room adjacent to that housing the training chambers. Reinforcers were Noyes 45 mg rat pellets.

Procedure

Training. All subjects were magazine trained and bar pressing was then shaped. The terminal training arrangement was then gradually approached—a multiple (*mult*) schedule consisting of two variable-interval (VI) schedules. On a VI schedule, reinforcement is produced by the first response occurring an average specified time, defining the particular VI, after the preceding reinforcement. One component

of this multiple schedule was signalled by a tone (T+ $\bar{L}$), the other by a light (L+ $\bar{T}$). The VI schedule values were chosen to establish differential rates to T+ $\bar{L}$ and L+ $\bar{T}$ S^Ds similar to those controlled by S^Ds in studies including S^A training reporting additive summation to compounded stimuli. [See Weiss (1969) and S^A training group in Exp. 2 of the present study.] At the termination of training, Subjects 65, 66, and 70 were on a *mult* VI 30-sec VI 120-sec schedule. Subject 72's low reinforcement density VI was reduced to VI 70-sec from VI 120-sec for its last six training sessions to maintain its low-density VI rate. Nevertheless, because most of its training sessions were composed of *mult* VI 30-sec VI 120-sec, for simplicity and clarity of exposition Subject 72's lower reinforcement density VI data are included with the data of the other subjects denoted by VI 120-sec.

After preliminary training, all subjects were given approximately fifty 2-hr multiple schedule sessions during each of which there were customarily between 100 and 130 reinforcements. The duration of the VI 30-sec component of this schedule varied between 4.5 and 10.5 min, with the other VI component approximately 1.5 times as long on average. The interreinforcement intervals of the VI 30-sec schedule had limits of 2 and 80 sec, the VI 70-sec 2 and 235 sec, and the VI 120-sec 2 and 300 sec. On all schedules, interreinforcement intervals were sequenced to keep time-to-reinforcement availability during any interval independent of the preceding interval. Subjects 65 and 70 had T+ $\bar{L}$ associated with their VI 30-sec schedules and L+ $\bar{T}$ with their VI 120-sec schedules. These stimulus-schedule combinations were reversed for Subjects 66 and 72. Subjects were introduced into, and removed from, the training chamber with one of the S^Ds on. This method guaranteed that they received no contact with light-out no-tone during training.

Testing. After the training described, all subjects were given a compounding test. This extinction test consisted of presentations of T+ $\bar{L}$, L+ $\bar{T}$, and the simultaneous presentation of tone-and-light (T+L). These stimulus conditions were presented in each of 18 block randomizations. Each test condition was presented 45 sec per block with a 15-sec light-out no-tone (T+ $\bar{L}$) period separating test conditions. Total test time was 54 min. Testing

commenced after an animal had received approximately 50 pellets on its training schedule.

RESULTS

At the termination of training, all subjects were clearly discriminating between S^D s signalling the two components of the multiple schedules. This control is shown graphically in Fig. 1, which presents terminal cumulative records of each subject, and quantitatively in Table 1. All subjects were responding at a higher rate during VI 30-sec than VI 120-sec S^D s before testing, and as can be noted from Fig. 1, these rates customarily changed rather abruptly with a change in stimuli.

Table 1
Terminal Training Response Rates
(responses per minute)
Experiment 1

Subject	Multiple Schedule Conditions	
	VI 30-sec S^D	VI 120-sec S^D
	$T+\bar{L}$	$L+\bar{T}$
	or $L+\bar{T}$	or $T+\bar{L}$
65	36.6	11.9
66	13.1	8.8
70	32.6	14.2
72	41.4	7.8
M	30.9	10.7

NOTE: These rates represent averages of the final five training sessions for each subject. The initial half-hour of each session was considered warmup and omitted from the determinations.

Total responses to each compounding test condition are presented in Table 2. Figure 2 presents the test results for individual subjects accumulated over sets of three successive test replications. (Each test condition was presented a total of 45 sec during each replication.) To make inter-subject comparison simpler, each data point is presented as a percentage of total test responses for that subject. The frames of Fig. 2 indicate that the test totals of Table 2 are basically representative of the behavior controlled by the respective test stimuli over the entire test for each subject. The behavioral equivalence, in terms of response outputs controlled, of $T+L$ and $\bar{T}+\bar{L}$ is especially striking over subjects. Averaging is consistently observed to both of these test conditions.

Table 2
Stimulus Compounding Test Responses
Experiment 1

Subject	Stimulus Conditions				Total Test Responses
		VI	VI		
		30-sec S ^D	120-sec S ^D		
	T+L	T+L̄	L+T̄	T̄+L̄	
		or L+T̄	or T+L̄		
65	189	222	125	193	729
66	130	168	100	142	540
70	262	443	203	262	1170
72	153	220	72	132	577
M	183.5	263.3	125.0	182.2	754.0
M%	24.7	34.3	16.4	24.6	100.0

DISCUSSION

The simultaneous presentation of two stimuli, each independently established as an S^D for one of two VI schedules, did not result in additive summation. Rather, response emission to compounded stimuli was intermediate between the rates controlled by the individual presentation of the VI 30- and VI 120-sec S^D s comprising it for all subjects, in spite of the wide range of rate differentials controlled by these S^D s over subjects in training. A detailed procedural comparison of this experiment with those stimulus compounding studies reporting additive summation is presented later in this paper. At present, it is sufficient to reiterate that the major procedural difference between Exp. 1 and those experiments is the extinction associated with the simultaneous absence of the VI S^D s—light-out no-tone—in the latter studies.

EXPERIMENT 2: CONSIDERATION OF RESPONSE AND REINFORCEMENT CONSEQUENCES OF S^A

The significance of S^A training to stimulus control in the stimulus compounding paradigm could be due to its signalling non-reinforcement, its producing rate differentiation between S^D presence and absence, or some interaction of both. Experiment 2 sought to isolate non-reinforcement from response differentiation effects of S^A training in summation designs. Two groups of animals were each trained on a three-ply multiple schedule. Tone ($T+\bar{L}$) and light ($L+\bar{T}$) were each S^D s for one of two VI schedules for both groups. The absence of these stimuli, $\bar{T}+\bar{L}$, signalled extinction (Ext)

Fig. 1. Cumulative records of subjects 65, 66, 70, and 72 from a terminal training session. The VI 30-sec contingency of the two-ply multiple schedule is effective when the base-line pen is in the lower register, the VI 120-sec contingency when it is elevated. Slash marks by the cumulative response pen record reinforcements. For subject 65 and 70, $T+\underline{L}$ was paired with the VI 30-sec schedule and $L+\overline{T}$ with the VI 120-sec schedule; the opposite stimulus-schedule combinations were employed for Subjects 66 and 72.

Fig. 2. The percentage of total test responses emitted to each test condition by the subjects of Exp. 1 accumulated over sets of three successive test replications. Stimulus conditions represented by each curve are identified in the legend presented in the upper left frame. T+L indicates the tone-plus-light condition. The presentation of T+ $\bar{L}$ or $\bar{L}$ + $\bar{T}$, as appropriate, is represented by the VI 30-sec and VI 120-sec curves. $\bar{T}$ + $\bar{L}$ denotes light-out no-tone.

for one group (S^A Training) and a (cf. Reynolds, 1961) differential-reinforcement-of-behavior-other-than-bar-pressing, food-reinforcement schedule for the second group (DRO Training). S^A and DRO stimuli both controlled response cessation to $\overline{T}+\overline{L}$, but while S^A was also correlated with non-reinforcement, DRO reinforcement density was maintained intermediate between that correlated with the two VI S^D s. Therefore, response cessation was isolated from non-reinforcement during $\overline{T}+\overline{L}$ to the extent that response cessation controlled by S^A within this schedule context is dynamically similar to that controlled by DRO.

METHOD

Subjects

Ten adult male Sprague-Dawley (hooded) rats, weighing approximately 350 g, were trained and tested at 80% of their free-feeding weights. They were housed in individual cages, with water continuously available, and were fed supplemental food rations directly after each training session. One animal had to be eliminated due to equipment malfunction.

Apparatus

Two training chambers similar to that described in Exp. 1 were used.

Procedure

Training. For clarity of exposition, the procedure is outlined in Table 3. All subjects were magazine trained; bar pressing was shaped, and followed by one 135-pellet session of VI 15-sec training. In Session 3, a three-ply multiple schedule was instituted. One group (S^A Training) was put on a multiple (VI 15-sec VI 15-sec Ext) schedule, and the other group (DRO Training) on a multiple (VI 15-sec VI 15-sec DRO 15-sec) schedule. The VI S^D s were tone ($\overline{T}+\overline{L}$) and light ($L+\overline{T}$). Light-out no-tone ($\overline{T}+\overline{L}$) followed each VI S^D and signalled both S^A and DRO. All subjects were kept on their respective schedules for three sessions during which the VI S^D s averaged 3 min in duration, $\overline{T}+\overline{L}$ periods 2.5 min, the DRO reinforcement requirement was 15 sec, and the VI schedules were increased to 22 sec each. These sessions, as well as all that followed, customarily lasted 3 hr or until approximately 135 pellets were received, whichever occurred first.

After the three multiple schedule sessions

described above, it was noticed, as has been reported by Reynolds (1961) and Nevin (1968), that the DRO contingency caused the VI rates for the DRO group to decrease. To overcome this response reduction, one of the VI components was altered to fixed ratio (FR) for Sessions 6 to 15. The other was gradually increased to a VI 60-sec by Session 15. Although response reduction to VI S^D s was not a problem with S^A subjects, they were given *mult* FR VI EXT training to keep them procedurally equated with DRO animals. The FR requirements for the various subjects ranged between 15 and 30. Although the FR sessions added an additional dimension to the training, this was judged preferable to having S^A and DRO subjects terminate training with different rates to the comparable VI components of their respective schedules. This would have made between-group comparisons extremely difficult because it might by itself affect response distributions in testing.

After the FR sessions, all subjects were given 20 additional training sessions before testing. In Session 16, and thereafter, the stimulus that had been correlated with FR was paired with a VI 30-sec schedule. Within approximately 10 sessions, all subjects were on the terminal schedules. These were *mult* VI 30-sec VI 90-sec EXT for the S^A group, and *mult* VI 30-sec VI 90-sec DRO 38-sec (approx.) for the DRO group. Each DRO subject was on a constant DRO during these sessions, but DRO values varied over subjects in order to achieve, for each subject, a reinforcement density during DRO that was in a range intermediate to the density received during its VI 30- and VI 90-sec schedules. Since DRO animals received reinforcers during a component when the responding of S^A animals was extinguished, their sessions were usually approximately 20% shorter than those of the S^A animals.

During Sessions 6 to 35, the VI S^D s, which averaged approximately 4 min each, were varied, between and within sessions, between the limits of 3 and 5 min. The termination of each VI component was followed by $\overline{T}+\overline{L}$ for both groups. Starting with Session 6, a correction procedure was superimposed upon the S^A contingency. S^A subjects were required to cease bar pressing for a minimum time during extinction for one of the VI S^D s to reappear. This no-response requirement was varied, within sessions between S^A periods. The limits of this

Table 3
Procedural Outline of Experiment 2

Composite Stimulus Continuum Session Duration		S ^a Training			DRO Training			Tone and Light (T+L)	
		Light Out, No Tone ($\bar{T}+L$)	Tone ($T+\bar{L}$)	or	Light ($L+\bar{T}$)	Tone ($T+\bar{L}$)	or		Light ($L+\bar{T}$)
1	To 50 Operant reinforcements	Magazine training Shaping	—	—	—	—	Magazine training Shaping	—	—
2	135 pellets	VI 15-sec. Sessions 3-35: $T+\bar{L}$ and $L+\bar{T}$ always followed by $\bar{T}+\bar{L}$; $\bar{T}+\bar{L}$ followed by $T+\bar{L}$ or $L+\bar{T}$. $T+\bar{L}$ and $L+\bar{T}$, 3-5 min.	—	—	—	—	VI 15-sec.	—	—
3	135 pellets	Extinction (2-3 min.)	VI 15-sec.	—	—	—	DRO ^c 15-sec.	VI 15-sec.	—
↓ ^b		Extinction	↓	—	—	—	↓	↓	—
5		(5 min.)	VI 22-sec.	—	—	—	VI 22-sec.	VI 22-sec.	—
		Sessions 6-35: Extinction w. correction ^d							
6	Three hours or 135 pellets	(30 sec.)	FR 10 ^c	↓	VI 30-sec.	↓	DRO 10-sec.	FR 10	VI 30-sec.
↓		↓	FR 25	VI 60-sec.	—	—	↓	FR 25	↓
15		(30-60 sec.)	VI 30-sec.	VI 60-sec.	—	—	DRO 30-sec.	VI 30-sec.	VI 60-sec.
16	135 pellets	(30-60 sec.)	↓	↓	VI 70-sec.	↓	DRO 30-sec.	VI 30-sec.	VI 60-sec.
↓		(30-70 sec.)	VI 30-sec.	VI 70-sec.	—	—	DRO 36-sec.	VI 30-sec.	↓
25		(30-90 sec.)	VI 30-sec.	VI 90-sec.	—	—	DRO 38-sec.	VI 30-sec.	VI 70-sec.
26-35	18 test re- plications (54 min.)								VI 90-sec.
36		45-sec. $T+\bar{L}$, $L+\bar{T}$ and $T+L$ presentations block randomized over replications, with 15-sec. of $\bar{T}+\bar{L}$ separating each presentation within replications. Reinforcement not available during test.							

^a — = Stimulus not presented during session.

^b ↓ = Schedules were gradually changed over sessions.

^c FR and DRO values are approximate. FR was manipulated for each subject to maintain responding at a substantial rate. DRO values were adjusted to permit receipt of a reinforcement density during $\bar{T}+\bar{L}$ that was in the range of the densities received during $T+\bar{L}$ and $L+\bar{T}$.

^d Extinction with correction demanded response cessation for prescribed time, varied within indicated limits within sessions, for a VI S^p to appear. A response during $\bar{T}+\bar{L}$ reset S^a timer. Each S^a subject was yoked to a DRO partner, indicated in Table 4, with respect to $\bar{T}+\bar{L}$ duration.

variation were 30 and 90 sec. A DRO subject was yoked to an S^A partner during training so that time during a $\overline{T}+\overline{L}$ period was determined by the performance of the S^A member of a pair. Minimum S^A times were set that would usually allow the DRO member to get at least one reinforcer even during the shortest S^A. The DRO reinforcement requirement, towards the end of training, was 38, 40, 36, and 38 sec for Subjects 33, 37, 42, and 44 respectively. Subjects 32, 33, 40, 44, and 46 had $T+\overline{L}$ associated with their VI 30-sec schedules and $L+\overline{T}$ with their VI 90-sec schedules. These stimulus-schedule combinations were reversed for Subjects 36, 37, 41, and 42.

Testing. A stimulus compounding test was performed in Session 36. This extinction test, identical to that described in Exp. 1, started after each subject received approximately 50 reinforcements on its normal training schedule.

RESULTS

Terminal Training Performance

Response rates. Table 4 presents terminal training rates, after warmup, of S^A and DRO subjects in each schedule-associated discriminative stimulus. It is clear that response rates over groups are ordered unsystematically within each schedule condition. Including warmup behavior in the determinations of Table 4 would have had an unsystematic effect on all rates except those in S^A, which would have increased for Subjects 32, 36, 40, 41, and 46 to 2.2, 3.8, 3.8, 5.9, and 1.6 responses per minute respectively—approximately a 50% average increase over values given in Table 4. Therefore, a warmup period appeared somewhat more significant for stable response reduction in $\overline{T}+\overline{L}$ for S^A than DRO subjects. Nevertheless, during initial acquisition of the multiple schedule discriminations through FR training (Sessions 3 to 15), the average responses, or errors, per minute over all sessions for S^A and DRO subjects during $\overline{T}+\overline{L}$ appeared equivalent. These rates were 12.8, 8.6, 11.4, 10.8, and 12.8 for S^A Subjects 32, 36, 40, 41, and 46 respectively, and 12.3, 10.6, 4.2, and 8.4 for DRO Subjects 33, 37, 42, and 44 respectively.

Reinforcement density. Reinforcements per minute in each reinforcement stimulus are presented for S^A and DRO subjects in Fig. 3.

Table 4
Terminal Training Response Rates
(responses per minute)
Experiment 2

S ^A				DRO			
Training Conditions				Training Conditions			
VI	VI	S ^A	DRO	VI	VI	DRO	DRO
30-sec	90-sec			30-sec	90-sec		
$T+\overline{L}$	$L+\overline{T}$			$T+\overline{L}$	$L+\overline{T}$		
or	or	$\overline{T}+\overline{L}$		or	or	$\overline{T}+\overline{L}$	
Subject	L+ $\overline{T}$	T+ $\overline{L}$	↓	Subject	L+ $\overline{T}$	T+ $\overline{L}$	↓
32	25.7	11.5	1.6	33	10.5	6.1	0.4
36	24.9	12.7	2.1	37	39.1	24.9	3.0
40	42.7	14.0	2.3				
41	65.8	23.9	4.2	42	25.1	8.9	2.2
46	21.8	7.1	1.4	44	45.7	19.1	1.2
M	36.2	13.8	2.3	M	30.1	14.8	1.7

NOTE: These rates represent averages of the final five training sessions for each subject. The initial half-hour of each session was considered warmup and omitted from the determinations. S^A and DRO subjects on each row were yoked with respect to $\overline{T}+\overline{L}$ duration. This time was determined by the S^A member.

Reinforcement densities during VI 30-sec and VI 90-sec SPs are comparable between groups, with the reinforcement density during DRO intermediate, for each subject, between its VI 30-sec and VI 90-sec densities.

Cumulative records. Figure 4 presents terminal cumulative records for two S^A and two DRO subjects, one subject within each group representing each of the stimulus-schedule combinations used in training. The essential similarity between these records graphically indicates that the between-group rate equivalence suggested in the quantitative training data of Table 4 is in fact indicative of the ongoing stimulus control. Differential rates occur consistently during VI 30-sec and VI 90-sec

Fig. 3. Reinforcements per minute during each reinforcement component of their multiple training schedules for subjects of the DRO and S^A groups. These rates represent averages of the final five training sessions for each subject. The initial half-hour of each session was considered warmup and omitted from the determinations.

Fig. 4. Cumulative records of Subjects 36, 40, 42, and 44 from a terminal training session. Subjects 36 and 40 are from the S^A training group; Subjects 42 and 44 from the DRO training group. The VI 30-sec contingency of the three-ply multiple schedule is effective when the base-line pen is in the lower register, the VI 90-sec when it is elevated. The solid portions of the base-line and depression of the cumulative response pen identify the light-out no-tone ($\bar{T}+\bar{L}$) periods. $\bar{T}+\bar{L}$ signalled S^A for Subjects 36 and 40 and DRO for Subjects 42 and 44. Slash marks by the cumulative response pen, whether upward or downward, record reinforcements. Both stimulus schedule combinations used in training are represented for each group. For Subjects 36 and 42, $L+\bar{T}$ was paired with the VI 30-sec schedule and $T+\bar{L}$ with the VI 90-sec schedule; the opposite stimulus schedule combinations were employed for Subjects 40 and 44.

S^Ds, usually from their onset; and responding ceases abruptly, or is severely reduced, immediately upon the presentation of $\overline{T}+\overline{L}$ irrespective of whether is signals S^A (Subjects 36 and 40) or DRO (Subjects 42 and 44). Terminal training data indicate no systematic qualitative or quantitative differences between S^A and DRO subjects, after initial warmup, on their respective schedules.

Test Performance

Table 5 gives total responses emitted during each test condition by subjects of both groups. Figures 5 and 6 present, for individuals of DRO and S^A groups respectively, the percentage of total test responses emitted during each test condition over consecutive blocks of three replications accumulated over the entire test. Although the total number of test responses emitted by S^A and DRO groups were essentially equivalent, they distributed these responses differently over conditions.

All subjects showed summation to T+L; but S^A animals exhibited clearly stronger summation. Figures 5 and 6 indicate that S^A subjects—32, 36, 40, 41, and 46—emitted 59, 62, 58, 58, and 63% of their total test responses respectively to T+L; while DRO subjects—33, 37, 42, and 44—emitted 41, 48, 45, and 39% respectively to that test condition. Nevertheless, both groups emitted essentially the same proportion of their test responses to $\overline{T}+\overline{L}$. Therefore, although they showed summation, DRO subjects emitted a higher proportion of their test responses to VI 30-sec and VI 90-sec S^Ds than did the S^A subjects.

DISCUSSION

In Exp. 1, where subjects received *mult* VI training, compounding the tone and light S^Ds independently correlated with each schedule produced response averaging in all subjects. Terminal training data, presented in Fig. 1 and Table 1, indicate that rates controlled by the respective VI S^Ds of that experiment are not characteristically distinguishable from those reported for subjects in similar compounding studies that incorporated S^A training during S^D absence. [See Weiss (1964, 1969) and the S^A subjects of Exp. 2.] Additionally, subjects of these three latter experiments, as well as those of Exp. 1, experienced about the same number of total training hours, approximately 100. It was necessary, however, to

employ somewhat larger reinforcement differences between VI components to get initial differential rate control in the *mult* VI VI schedule of Exp. 1 than in the *mult* VI VI EXT schedules of the other experiments just cited. It seems extremely unlikely, however, that the 4:1 reinforcement ratio between VI schedules of Exp. 1 contributed significantly to the response averaging reported to compounded S^Ds in that study. The S^A trained subjects of Exp. 2, which experienced reinforcement ratios of at least 3:1 between VI schedules, showed additive summation to compounded VI S^Ds as substantial as has ever been reported. On average, the response output controlled by T+L for these subjects was 1.7 times the combined output to $\overline{T}+\overline{L}$ and $L+\overline{T}$ S^Ds. Therefore, the results of Exp. 1, taken in the context of other comparable compounding studies cited, suggest that the behavioral effects of S^A training have been integral to previously reported instances of additive summation. This conclusion would imply that the failure of Lawson, Mattis, and Pear (1968, Exp. 2) to find additive summation to combined S^Ds after *mult* VI 45-sec VI 45-sec training was probably not due to the fact that qualitatively different reinforcers maintained responding to their respective tone and light S^Ds, as those authors suggest, but rather to the absence of S^A in their training procedure.

Experiment 2 considered the contributions of the response differentiation and nonreinforcement consequences of S^A training to additive summation. Before testing, the DRO and S^A trained subjects of that experiment were behaviorally similar with respect to response rates in the three components of their multiple training schedules. Responding was maintained by VI schedules during $\overline{T}+\overline{L}$ and $L+\overline{T}$, and was severely reduced, or ceased completely during $\overline{T}+\overline{L}$. Response differentiation alone between $\overline{T}+\overline{L}$ and the VI S^Ds appeared adequate for DRO subjects to show additive summation to T+L. However, the clearly greater summation exhibited to that test condition by the S^A trained subjects indicates that the response differentiation, as well as the nonreinforcement consequences of S^A training, contribute to the magnitude of response enhancement to compounded S^Ds. Recent data suggest that these same variables might operate in determining the magnitude of another behavioral phenomenon of interest to students of

Table 5
Stimulus Compounding Test Responses
Experiment 2

Stimulus Condition												
Sub- ject	S ^a Training						DRO Training					
	T+L	VI 30-sec. S ^p		VI 90-sec. S ^p		Total Test Re- sponses	Sub- ject	T+L	VI 30-sec S ^p		VI 90-sec S ^p	
		T+ $\overline{\text{L}}$	or L+ $\overline{\text{T}}$	T+ $\overline{\text{T}}$	or T+ $\overline{\text{L}}$				L+ $\overline{\text{T}}$	or T+ $\overline{\text{L}}$		
32	509	117	201	858	33	33	96	68	54	16	234	
36	377	120	74	608	37	37	517	321	194	37	1069	
40	334	102	113	572	42	42	233	182	61	37	513	
41	617	325	47	1057	44	44	331	278	163	48	820	
46	162	36	58	262	M	M	294.3	212.3	118	34.5	659.0	
M	399.8	140	98.6	671.4	M	M	44.7	32.2	17.9	5.2	100.0	
M%	59.6	20.8	14.7	100.0	M%	M%						

DRO TRAINING

Fig. 5. The percentage of total test responses emitted to each test condition by individual DRO subjects of Exp. 2 accumulated over sets of three test replications. Stimulus conditions represented by each curve are identified in the legend presented in the upper left frame. T+L indicates the tone-plus-light condition. The presentation of T+ $\bar{L}$ or L+ $\bar{T}$, as appropriate, is represented by the VI 30-sec and VI 90-sec curves. T $\bar{+}$ L $\bar{+}$ represents the DRO condition for these subjects and the S^Δ condition for those of Fig. 6.

Fig. 6. The percentage of total test responses emitted to each test condition by individual S^A subjects of Exp. 2 accumulated over sets of three test replications. See caption of Fig. 5 for explanation.

stimulus control that is defined by response enhancement—peak shift (*cf.* Hansen, 1959). In fact, several recent lines of evidence indicate that there could be an underlying functional similarity between peak shift and summation. These will be discussed in turn, commencing with data most directly relevant to Exp. 2 of this study.

Interest in the relationship between contingencies maintaining stimulus differentiation to intradimensional training stimuli and subsequent peak shift during generalization testing is exemplified by investigations of Terrace (1966, 1968), Yarczower, Dickson, and Gollub (1966) and Yarczower, Gollub, and Dickson (1968). In particular, Yarczower *et al.* (1968) indicate that reinforcement relations between training stimuli might operate similarly in determining peak shift, as the results of Exp. 2 suggests they operate in determining response distributions during compounding tests. Directly relevant to the findings of Exp. 2 are two groups of pigeons Yarczower *et al.* (1968) trained on a hue discrimination that associated a wavelength of 550 nm with VI and 570 nm with DRO schedules. Group 1 received equivalent reinforcement density during VI and DRO, while Group 3 received three times the reinforcement density during DRO than VI. The group with equivalent reinforcement densities during VI and DRO S^Ds, which might be compared to the DRO group of Exp. 2, produced area shift during generalization testing, but the other group did not. Unfortunately, comparisons between these groups must be made cautiously because they differed in more than just reinforcement rate during DRO. Nevertheless, the Yarczower *et al.* (1968) data could indicate that relative reinforcement density between training stimuli, as well as response factors, operate to determine degree of peak shift. Applied to the data of Exp. 2, this would suggest other things being equal, that as DRO reinforcement density during $\overline{T+L}$ increases in relation to the density received during $T+\overline{L}$ and $L+\overline{T}$ VI S^Ds, the proportion of total test responses emitted to a $T+L$ compound would decrease. Parametric investigation is necessary to confirm this.

Wolf (1963) was the first to postulate that the composite stimulus dimension employed in summation experiments might be functionally equivalent to the unitary dimensions of the peak shift studies. A "... composite continuum

is defined by the on-off states of all relevant discriminative or conditioned stimuli, one continuum extreme anchored to the all-off state, the other to all on. The points between these continuum extremes are scaled with reference to the number of elements common to each . . . the number of points on any composite scale being equal to the number of independently conditioned S^Ds . . . plus one" (Weiss, 1969, pp. 22-23).

The two-element composite continuum of the present experiments might be conceptualized as extending from the all-off extreme ($\overline{T+L}$) through the one-stimulus on condition ($T+\overline{L}$ or $L+\overline{T}$), to the all-on extreme ($T+L$). (This continuum can be seen in the stimulus identification row of Table 3.) Wolf (1963) and Weiss (1964) were the first to report that subjects showed additive summation to $T+L$ in testing, when responding in training was extinguished in $\overline{T+L}$ and maintained through reinforcement in $T+\overline{L}$ and $L+\overline{T}$. The response enhancement effect of compounding studies was likened to that of peak shift because, on the composite continuum, $T+L$ can be seen as further removed from $\overline{T+L}$ (S^A) than either $T+\overline{L}$ or $L+\overline{T}$ S^Ds; just as in peak shift, maximum responding is controlled by a stimulus removed from S^D in a direction away from S^A.

Weiss (1969) contributed additional evidence to this peak shift-summation comparison by demonstrating that the reversibility of function between S^D and S^A values along the unitary dimensions employed in peak shift studies was also possible along the composite continuum postulated to underlie summation. When he extinguished his subjects' responding to $T+L$ while maintaining it with VI schedules to $T+\overline{L}$ and $L+\overline{T}$, he found that they showed additive summation to the composite furthest removed from $T+L$, $\overline{T+L}$. It therefore appeared that either extreme of the composite continuum employed in these studies could serve equally well as S^A, just as 550 or 570 nm, for example, can be employed as S^A to produce peak shift. In addition, the test results of Exp. 1 suggest that when only the value defining the intermediate point on a two-element composite continuum is experienced, the two extremes, $T+L$ and $\overline{T+L}$, are behaviorally equivalent in their capacity to control response emission.

Peak shift and summation can be observed

in either direction along their respective continua, but intradimensional discrimination training is necessary for both phenomena. According to Yarczower *et al.* (1966), the crucial product of this training for peak shift is rate difference between stimuli on the continuum to be tested. They conclude that generalization gradient peaks will be shifted away from the stimulus controlling the lower rate. Yarczower *et al.* and Terrace (1968) insist that this low rate must be the product of rate reduction if peak shift is to be observed. This rate reduction according to Terrace is also accompanied by contrast (*cf.* Reynolds, 1961), *i.e.*, an increase in rate to the stimulus in the schedule left undisturbed, in training.

Unfortunately, contrast data are not available for the S^A or DRO trained subjects of Exp. 2 because discrimination training was instituted during the second training session before rates stabilized. However, in comparing the response rate in $\overline{T+L}$ during the first 13 sessions with that of the last five, a substantial rate reduction is noted for both S^A and DRO subjects, a condition that Terrace (1968) suggests is sufficient to produce contrast. A non-differentially trained group of animals, which respond at equivalent rates to extreme ($\overline{T+L}$) and intermediate ($T+L$ and $L+T$) composite stimuli in training would probably not summate to $T+L$ test presentations. However, if after stabilizing on this nondifferential training schedule responses were extinguished in the presence of the composite training extreme, the rate reduction reported to $\overline{T+L}$ in Exp. 2 would lead one to anticipate positive contrast to the intermediate composites still associated with reinforcement.

Assuming the contrast predicted in the preceding paragraph would be measurable under the appropriate conditions after S^A training, the FR scheduled during an intermediate composite S^D early in training in Exp. 2 probably made DRO subjects more closely comparable functionally to their S^A counterparts by maintaining and even increasing the rate controlled by these S^Ds, rather than allowing it to decrease (see Nevin, 1968). The distribution of test responses after S^A training is almost identical to that reported for similarly trained animals that had no FR training in one of their intermediate composite S^Ds (Weiss, 1969, p. 26). Comparable comparison groups are not available for the DRO trained subjects.

At the minimum, rate differences between values along a unitary stimulus dimension appear necessary for peak shift. Recently, Weiss and Emurian (1970) suggested that "what might be necessary for [additive] summation... is differential rates controlled by extreme and intermediate composite stimuli in training" (p. 209), with the rate controlled by the composite training extreme lower than those controlled by the intermediate composites. (This assumes that the performances controlled by the intermediate composites are not incompatible as may be the case when VI and DRL schedules are employed (Weiss 1967).) Experiment 2 showed, though, that reinforcement as well as rate factors are involved in determining the final distribution of responses during stimulus compounding and the preceding discussion suggests in addition that the processes underlying behavioral contrast could be involved. Finally, the functional similarities noted between peak shift and summation indicate, where the characteristics of the respective continua permit, that many of the variables relevant to the former phenomenon deserve attention in studying the latter.

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Received 1 December 1969.