*EFFECTS OF SIGNALS PRECEDING AND FOLLOWING
SHOCK ON BASELINE RESPONDING DURING A
CONDITIONED-SUPPRESSION PROCEDURE¹*

HANK DAVIS, JOHN MEMMOTT,² AND HARRY M. B. HURWITZ

UNIVERSITY OF GUELPH

Long-Evans rats were exposed to a succession of conditioned-suppression procedures involving pairings of (1) signal-shock, (2) shock-signal, and (3) a signal-shock-signal sequence in which first and second signals were at first physically identical. Traditional suppression of food-reinforced responding was obtained under the signal-shock arrangement, and exposure to the shock-signal sequence resulted in conditioned enhancement of responding during the signal. The signal-shock-signal condition reliably suppressed responding during the first signal, but produced no differential effect on response rate during the second signal. Baseline responding was least changed from preshock rates under the signal-shock-signal procedure, but baseline rate was considerably reduced under the signal-shock and shock-signal arrangements, the latter yielding most substantial reductions. A second experiment indicated that the magnitude and direction of changes in baseline responding reported in Experiment I were not confined to cases in which the first and second signals in the signal-shock-signal arrangement were physically identical. It is suggested that the major effects of the conditioned-suppression procedure on response rate might not be confined to presentations of the signal.

Key words: conditioned suppression, acceleration, baseline rate, shock, rats

The original purpose of these experiments was to investigate the possibility of conditioning suppression and acceleration to the same stimulus in a conditioned-suppression context. The procedure involved a somewhat unorthodox signal-shock-signal sequence in which a common exteroceptive stimulus (CS) both preceded and followed shock (US).

In the course of collecting these data, however, a peripheral facet of the results emerged and ultimately took precedence over the original issue of differentially conditioning suppression and acceleration. This observation concerned substantial changes in baseline rates of response, rather than rate changes during presentations of the CS. The notion that baseline response rate might provide a sensitive behavioral measure of the suppressive effects of a CS-US procedure is not widely accepted in the conditioned-suppression literature (see re-

views by Davis, 1968; Lyon, 1968). Although some experiments have reported general decreases in baseline responding during conditioned suppression (*e.g.*, Annau and Kamin, 1961; Hendry and Van Toller, 1965; Hunt and Brady, 1955), few experimenters have expressed suppressive effects in terms of changes in baseline rate obtained throughout a session. Davis and McIntire (1969), however, noted the importance of this measure in an experiment that examined baseline responding in relation to various CS-US contingencies. They noted for example, that the principal effect of a no-contingency procedure, under which signals and shocks were randomly interspersed throughout each session, was a severe disruption, and sometimes a complete loss, of the behavioral baseline.

Other investigators have confirmed that the CS-US contingency can exert powerful effects on baseline behavior. Seligman (1968) reported that rats that experienced a positive contingency between CS and shock showed reduced baseline response rates during the early training sessions but gradually recovered their preshock baselines as the experiment progressed. However, when shocks could occur at any time in the absence of a CS-US contingency, rats almost ceased responding through-

¹This research was supported in part by Grant No. A8264 from the National Research Council of Canada to Harry M. B. Hurwitz and by a grant from the University of Guelph Research Advisory Board to Hank Davis. Reprints may be obtained from Hank Davis, Department of Psychology, University of Guelph, Guelph, Ontario, Canada N1G 2W1.

²Now at the University of Western Ontario, London, Ontario, Canada.

out the experimental session. Moreover, Seligman and Meyer (1970) found no sign of recovery of baseline responding for up to 70 experimental sessions during which CS and US were randomly related.

In an extensive investigation of how baseline responding is affected by the CS-US contingency, Nageishi and Imada (1974) modified Seligman's (1968) procedure to include signal-shock contingencies that were intermediate in predictiveness. They found that as the predictability of shock declined by gradually degrading the CS-US contingency, baseline behavior progressively deteriorated. These results suggest that predictability of shock under a positive contingency may be a necessary condition for recovery of baseline behavior within the conditioned-suppression context.

All of the above conditioned-suppression studies were unorthodox in that they focused attention on changes in the behavioral baselines themselves, rather than on responding during the CS. All of these studies suggest that an examination of baseline responding may be fundamental to the analysis of conditioned-suppression procedures. Work in our laboratory has continued to suggest the importance of this measure, although never as forcefully as the data that emerged in the present study.

EXPERIMENT I

Recent conditioned-suppression experiments have indicated that either suppression or acceleration of food-reinforced responding could be independently conditioned, depending on whether the CS predicted the presence or the absence of shock (*e.g.*, Davis and McIntire, 1969). There have also been a number of studies in which a signal paired with shock (CS+), and a second signal explicitly paired with absence of shock (CS-), have both been presented. These differential conditioning experiments (*e.g.*, Hammond, 1966; Ray and Stein, 1959) have reported suppression of food-reinforced responding to CS+ and varying degrees of acceleration to CS-, upon which shock was never contingent. The strongest indication of conditioned acceleration occurred in Hammond's study, in which CS+ and CS- were "markedly different from each other". No studies reported to date, however, have attempted to condition both suppressive and accelerative effects to the same signal.

The procedure in Experiment I involved presenting the same signal both before and immediately after shock in a CS-US-CS sequence. The suppressive effects of a CS preceding shock have been amply demonstrated (*e.g.*, Estes and Skinner, 1941). Regarding the US-CS arrangement, Rescorla (1969) argued that inhibition of conditioned "fear" is produced by such "negative contingency" procedures, and Moscovitch and LoLordo (1968) demonstrated that a backward conditioning arrangement is effective in producing a "fear inhibiting" CS, which could be expected to accelerate food-reinforced baseline operant responding. The present operations could therefore result in either suppression or acceleration to the same CS, depending on its context. Because these possible outcomes imply comparisons between a subject's "normal" degree of conditioned suppression or acceleration and that resulting from the CS-US-CS condition, a multiphase design was employed in which subjects were exposed to traditional CS-US or US-CS contingencies, as well as to a CS-US-CS arrangement.

METHOD

Subjects

Nine experimentally naive male hooded rats of the Long-Evans strain were 110 to 120 days old when introduced into the experiment and weighed between 345 and 439 g. The rats were individually housed and had free access to water. After each experimental session, they were given access to food for approximately 90 min, which maintained body weights at 75 to 80% of free-feeding weights.

Apparatus

The apparatus consisted of three rodent test chambers and enclosures, equipped with retractable levers (Campden Instrument Co.). The floor of each chamber consisted of 16 stainless-steel grids, 0.9 cm in diameter and spaced 0.9 cm apart. The lever could be activated by a minimum downward force of 0.09 N. Noyes pellets (45 mg) could be delivered into the food hopper situated in the lower center wall of the chamber beside the response lever. A constant-current shock generator (Campden Instrument Co.) delivered scrambled current to the grids, walls, and lever of each chamber. Shock intensity was set at 0.8 mA with a duration of 1.5 sec. Delivery of shock served as the

US. The CS was a 1-min tone provided by a Mallory Sonalert (Model SC-628H) affixed to the top center of the ceiling of the chamber and monitored at 86 dB (ref: 0.0002 dynes/cm²). Continuous white noise masked extraneous sound.

Preliminary Training

For the first two days following magazine and lever-press training, each subject was permitted to obtain 100 reinforcements under a continuous reinforcement schedule. During the next three days, subjects were trained to respond on a variable-interval (VI) 60-sec reinforcement schedule (range nine to 210 sec) with 5-sec limited-hold contingency. For the remainder of the experiment, subjects were tested daily in 90-min experimental sessions. The VI 60-sec schedule was maintained throughout the experiment.

Training on the VI schedule (Phase I) was complete when visual inspection of cumulative response records revealed stable baselines. Each subject was then given two sessions of pre-exposure to the 1-min tone CS in the absence of shock. CS presentations occurred on the average every 11 min with an interstimulus range of 2.5 to 18 min. The reinforcement schedule was continuously in effect both during and between CS presentations. Inspection of the cumulative records at the end of the adaptation sessions indicated that the CS had no appreciable effect on baseline response rate.

At the conclusion of Phase I, the nine subjects were randomly assigned to one of three experimental groups. Treatment of these groups, which varied according to CS-US contingency during Phases 2 to 4, is discussed below and is summarized in Table 1. Each experimental phase was in effect for between 18 and 25 sessions. Phases were changed when a

criterion for stability of baseline responding (standard deviation <10% mean responses per session) was met for 10 consecutive sessions.

CS-US Contingency

The CS-US treatment is an example of a positive contingency (see Rescorla, 1967). Each CS preceded and terminated at the onset of the US. This experimental arrangement is known to yield conditioned suppression during the CS.

The US-CS treatment is a special case of the negative contingency (Rescorla, 1967). Each US preceded and terminated at onset of the CS. This experimental arrangement typically results in conditioned acceleration of responding during the CS (Davis and McIntire, 1969).

The CS-US-CS treatment, involving a common exteroceptive CS, contains both positive and negative contingencies, and might therefore yield both conditioned suppression and acceleration. The first CS preceded and terminated at US onset. The second CS began at the moment of US offset.

Following contingency manipulations in Phase 4, all subjects were exposed to a final experimental phase in which the baseline VI food schedule alone was in effect, with all presentations of CS and US suspended.

RESULTS

The results are summarized in Tables 2 and 3 and described below. The effects of conditioned stimuli on baseline response rate are expressed in terms of absolute rates of responding and as CS ratios. CS ratios were computed from an $A/A + B$ ratio, where A is the mean response rate during CS periods and B is the mean response rate in non-CS periods. The CS ratio has upper and lower limits of 1.00 and 0.00, indicating maximal conditioned acceleration and conditioned suppression, respectively. A CS ratio of 0.50 indicates no differential effect of the CS on response rate.

Group I

Subjects in this group were exposed to a traditional conditioned-suppression (CS-US) procedure in Phases 2 and 4. During both of these periods, the CS that preceded shock clearly suppressed baseline food-reinforced responding and resulted in suppression ratios ranging from 0.01 to 0.06. There was no

Table 1

Experiment I treatment of each of three groups (N = 3) during five consecutive phases of 18 to 25 sessions each.

Phase	Group		
	I	II	III
1	Baseline VI food schedule only		
2	CS-US	US-CS	CS-US-CS
3	CS-US-CS	CS-US-CS	CS-US-CS
4	CS-US	US-CS	CS-US-CS
5	Baseline VI food schedule only		

Table 2
CS Ratios Obtained during Final Five Sessions of Each Phase in Experiment I

Subject	Phase 2		Phase 3		Phase 4	
	First CS Ratio	Second CS Ratio	First CS Ratio	Second CS Ratio	First CS Ratio	Second CS Ratio
GROUP I (CS-US)						
1	0.06	(0.33) ^a	0.06	0.31	0.06	(0.31) ^a
2	0.01	(0.47) ^a	0.01	0.38	0.01	(0.43) ^a
3	0.01	(0.47) ^a	0.01	0.46	0.01	(0.42) ^a
GROUP II (US-CS)						
4	—	0.79	0.04	0.58	—	0.92
5	—	0.75	0.04	0.48	—	0.83
6	—	0.97	0.03	0.63	—	0.95
GROUP III (CS-US-CS)						
7	0.01	0.52	0.05	0.49	0.01	0.43
8	0.03	0.49	0.02	0.50	0.03	0.45
9	0.02	0.56	0.01	0.50	0.04	0.50

^aAlthough no exteroceptive CS was presented during this period, ratio values were computed for responding during the comparable unsignalled 1-min period.

change in any animals' suppression ratio between Phases 2 and 4, despite the intervening experimental condition (CS-US-CS) in Phase 3. The only difference apparent in the data obtained during Phases 2 and 4 was in the behavioral baselines themselves, rather than in effects differentially conditioned to the CS (see Figures 1 and 2). During initial exposure to the conditioned-suppression procedure in Phase 2, baseline response rates were reduced to between 13 and 46% of their preshock (Phase 1) values for all subjects. In every case, however, some recovery of baseline responding occurred during Phase 4, when responding returned to between 50% and 73% of Phase 1 response rates. This recovery may have appeared as a carryover effect from Phase 3, during which subjects were exposed to the CS-US-CS procedure. Despite the addition of this second CS immediately following shock, there was no change in the degree of conditioned suppression to the first CS from the level observed in Phase 2 or Phase 4. Moreover, the addition of a CS in the minute following shock did not appear to alter the CS ratio beyond the value previously obtained when the period was unsignalled.

The clearest difference in behavior stemming from the introduction of a second CS in Phase 3 was the dramatic elevation of baseline responding. The partial recovery of these rates during Phase 3 was maintained throughout Phase 4, despite elimination of the second

CS (see Figures 1 and 2). During the final experimental sessions (Phase 5), in which all CS and US events were withheld, each subject's baseline responding was restored to near equivalence with its Phase 1 rate, although a slight residual suppression, ranging between a 1% and 12% reduction, remained.

Group II

Subjects in Group II were exposed to a negative contingency US-CS arrangement during Phases 2 and 4. All subjects showed a clearly accelerative effect of the CS on response rate in the minute following shock. CS ratios ranged between 0.75 and 0.97 in Phase 2, and reappeared virtually unchanged when the conditions were repeated in Phase 4, ranging between 0.83 and 0.95. Whereas the CS had clear accelerative effects on responding relative to baseline during Phases 2 and 4, baseline response rates themselves were drastically reduced, falling to an average below 10% of the preshock baselines (see Figure 2).

The addition of a CS before shock in Phase 3 resulted in a number of marked changes in behavior. Conditioned suppression to the first CS appeared for all subjects; this effect, however, was accompanied by a loss of acceleration to the second CS, previously seen in Phase 2. It is important to note that this loss of acceleration did not stem from a decline in responding during the CS. Rather, reduced conditioned acceleration resulted from an increase

Table 3
Average Number of Responses during CS₁, CS₂, and Baseline for Final Five Sessions of Each Phase in Experiment I

Subject	Phase 1		Phase 2						Phase 3						Phase 4						Phase 5	
	Baseline Resp Rate/ Min	Min	CS ₁ Resps/ Min	CS ₂ Resps/ Min	Base-line		% Phase I	CS ₁ Resps/ Min	CS ₂ Resps/ Min	Base-line		% Phase I	CS ₁ Resps/ Min	CS ₂ Resps/ Min	Base-line		% Phase I	Base-line Resp Rate/ Min	Phase 5 Base-line Resp Rate/ Min			
					Resps/ Min	Resps/ Min				Resps/ Min	Resps/ Min				Resps/ Min	Resps/ Min						
GROUP I (CS-US)																						
1	55.5		0.46	3.55	7.22	13%	2.10	14.71	32.75	59%	2.16	15.22	33.86	61%				52.2				
2	51.6		0.14	12.81	14.45	28%	0.27	16.45	26.83	52%	0.26	19.46	25.80	50%				51.0				
3	50.5		0.23	20.60	23.33	46%	0.35	29.69	34.85	69%	0.37	26.71	36.87	73%				45.0				
GROUP II (US-CS)																						
4	63.6		—	23.90	6.36	10%	1.74	56.50	41.70	66%	—	73.14	6.36	10%				42.3				
5	39.5		—	10.68	3.56	9%	0.65	14.10	15.60	40%	—	21.24	4.35	11%				34.1				
6	51.7		—	33.33	1.03	2%	0.99	53.80	32.30	63%	—	39.40	2.07	4%				47.5				
GROUP III (CS-US-CS)																						
7	43.9		0.45	48.30	44.60	102%	2.68	48.92	50.92	116%	0.78	58.61	77.70	177% ^a				94.0 ^a				
8	62.3		2.10	63.80	66.40	107%	1.35	66.04	66.04	106%	1.99	52.21	64.17	103%				75.3				
9	34.5		0.43	26.80	21.04	61%	30.00	30.02	30.02	87%	1.25	30.03	30.02	87%				43.4				

*The difference between Phase 1 and Phase 5 response rates is due to a change in response topography that occurred during Phase 4. When Phase 4 rate is calculated as a per cent of final Phase 5 rate, rather than of Phase 1 rate, value obtained is 83%.

Fig. 1. Illustrative cumulative response records for subjects in Group I. A traditional (*i.e.*, CS-US) conditioned suppression procedure was in effect during Phases 2 and 4, and a CS-US-CS procedure was used during Phase 3. Blips on record indicate presence of US; first CS occurrences are shown immediately below each record.

in baseline responding that occurred after the first CS was introduced (see Figures 3 and 4). As the accelerative effect was dissipating during Phase 3, the overall rates of responding rose dramatically and baselines recovered to values ranging between 40 and 66% of pre-shock (Phase 1) rates. Re-instatement of the US-CS procedure in Phase 4 again produced a deterioration of baseline response rates. When CS and US events were withdrawn during Phase 5, baseline responding partially recovered, but did not, in any case, approach Phase 1 values.

Group III

Subjects in Group III were maintained on the CS-US-CS condition throughout Phases 2 to 4. The results of this manipulation remained fairly stable throughout approximately 60 experimental sessions. The CS that preceded shock resulted in conditioned suppression for all subjects; ratios ranged from 0.01

to 0.05. When the CS followed shock, there was essentially no effect on baseline responding; ratios ranged from 0.43 to 0.56, indicating equivalence between responding in this period and non-CS minutes of the session. The most striking result of this manipulation, however, was that little or no reduction in overall response rate occurred from levels recorded before shock was introduced. This effect is clearly seen in Figures 5 and 6 and, in comparison to Group II, suggests that presence of the first CS has a massive influence on baseline responding, facilitating baseline recovery when present and disrupting baseline responding when absent.

The case of Subject 7, which showed an increase in baseline rate in Phase 4 to 177% of its Phase 1 level, requires further comment. Examination of this subject's bar-pressing behavior showed that this increased rate of responding was attributable to a new response topography of "fluttering" the bar. Thus, to

Fig. 2. Mean number of responses during CS₁, CS₂, and baseline (non-CS portions of session) for final five sessions of each phase of experiment for Group 1.

evaluate this subject's baseline responding in Phase 4, it may be appropriate to consider the rate of response obtained in Phase 5, rather than the Phase 1 rate. Subject 8 showed no appreciable change in overall rate of response between Phases 1 and 4. Subject 9 showed the greatest indication of baseline disruption of Group III; however, this effect dissipated across phases, and rose to a final total of 87% of preshock baseline rate.

DISCUSSION

The most important, and unexpected, finding of Experiment I is the fact that the CS-US, US-CS, and CS-US-CS procedures exerted their differential effects on the behavioral baselines themselves, as well as on response rates during CS presentations. For instance, it is now clear that the dominant characteristic of the conditioned acceleration (US-CS) procedure, be-

yond increasing response rate during the CS, is the drastic overall reduction in the rate of response produced throughout the session. In fact, it may well be that this general suppression of responding is not simply a subsidiary property of conditioned acceleration, but rather a necessary condition for obtaining it. In short, unless the baseline is substantially reduced, conditioned acceleration may not be obtainable. This notion is consistent not only with present data, but also with previous reports of conditioned acceleration (Davis and McIntire, 1969; Hammond, 1966).

Figures 3 and 4 show clearly that Group II's loss of conditioned acceleration after the first CS was added in Phase 3 occurred because of the increase in baseline responding that resulted from this manipulation, and not because of conflicting (suppressive) effects conditioned to the same CS. In fact, this analysis

Fig. 3. Illustrative cumulative response records for subjects in Group 2. A conditioned acceleration (US-CS) procedure was in effect during Phases 2 and 4, and a CS-US-CS procedure was used during Phase 3. US occurrences are indicated by blips on each record; instances of CS occurrence are indicated directly below each record.

applies not only to Group II, but to all occasions on which CSs were presented both before and after shock. It may be that the failure to observe conditioned acceleration in all of these cases stems from the fact that the baseline rate of responding had risen to a value higher than that allowable for demonstrating conditioned acceleration to the CS.

If one views the behavioral baseline as a sensitive measure of the degree of aversion in a conditioned-suppression situation, it is then possible to speculate further about each of the present procedures. For instance, it is not surprising that the US-CS condition generated the greatest reduction in baseline. Under this condition, there is an almost constant threat of shock insofar as no stimulus reliably precedes its onset (*cf.* Seligman, 1968). This situation is similar to the Pavlovian discussion of the "synthetic environmental reflex", a generalized conditioned response to the experimental situation itself, in the absence of a reliable extero-

ceptive stimulus (1927, p. 115). Recent research has shown that the occasional delivery of shock in the absence of a warning signal results in a marked and extensive disruption of appetitively maintained responding. The intensely suppressive nature of this procedure was demonstrated in a situation in which virtually all baseline responding remained suppressed, and showed no sign of recovery, for up to 70 sessions of unpredictable shock (Seligman and Meyer, 1970). These and related findings led Seligman (1968) to propose that a crucial variable controlling behavior in aversive situations is the presence of a reliable predictor of "safe" (*i.e.*, shock-free) periods. Hence, it is not surprising that in the present experiment responding during "safe" CS periods following shock was accelerated for Group II relative to responding in "danger" periods represented by absence of the CS. Similar instances of post-shock rate acceleration have also been observed in the absence of an exteroceptive CS.

Fig. 4. Mean number of responses during CS₁, CS₂, and baseline (non-CS portions of session) for final five sessions of each phase of experiment for Group 2.

For instance, Davis, Memmott, and Hurwitz (1975) reported situations in which constraints in the scheduling of shocks created a stimulus situation in which the delivery of shock, itself, provided a basis for predicting periods free from shock. When this happens, as with the use of a minimum 1-min intershock interval, responding is typically accelerated for a short period of time following shock offset.

The degree of general baseline suppression produced by the CS-US condition, while considerably less than that resulting from US-CS, is still somewhat surprising. This may be partly due to the fact that investigators do not typically report changes in overall baseline rates in terms of suppression from preshock values (see reviews by Davis, 1968; Lyon, 1968). It is still reasonable, however, that some degree of general suppression would occur if one considers that although shock is totally predict-

able, the CS that signals shock has itself become aversive and might occur at any moment. It is most probably this aspect of continual "threat of the CS" that results in the intermediate degree of baseline suppression found under traditional CS-US conditions. Were the unpredictable CS less aversive, *e.g.*, derived from a procedure under which signalled shock were avoidable (*e.g.*, Sidman and Boren, 1957), then the resultant degree of general baseline suppression might very well be correspondingly less.

It is not readily apparent why the addition of a second CS following shock would remove such a considerable degree of aversion from the conditioning situation and leave behavioral baselines least changed from preshock rates. There is little question, however, that this is precisely what happened whenever the CS-US-CS condition was imposed: for Groups

Fig. 5. Illustrative cumulative response records for subjects in Group 3. A CS-US-CS procedure, involving a common exteroceptive CS, was in effect throughout the experiment. US occurrences are indicated by blips on the records and presence of first CSs is noted immediately below record.

I and II during Phase 3, and for Group III throughout the experiment. Since it is clear that a second CS offers no additional help in predicting shock occurrence, it is again appropriate to view the situation in terms of "threat of the CS". Under the CS-US-CS condition, there is a unique additional margin of "safety" in that not only are all US occurrences totally predictable, but all "threat" of the conditioned aversive first CS is absent during presentation of the second CS. It is not clear why this effect generalizes to the absence of either CS.

The present experiment also explored the possibility of differentially conditioning both suppressive and accelerative effects to the same CS within a single session. The results indicate that while either of these effects may be conditioned independently, it does not appear feasible to combine these antagonistic functions within a single stimulus. Moreover, as Groups I and II demonstrate, it is the suppressive effect alone that survives the compound procedure.

EXPERIMENT II

The addition of a second CS in a CS-US-CS sequence produced a relative enhancement of baseline responding in a conditioned-suppression procedure. Experiment II explored the generality of this effect by investigating whether the first and second CSs need to be physically identical to produce such response-rate enhancement. Experiment II employed a similar multiphase design to that used in Experiment I.

METHOD

Subjects

Nine male Long-Evans rats, similar in weight, age, and experimental handling to those used in Experiment I, served.

Apparatus

Identical to Experiment I. In addition to the Mallory Sonalert used to generate CS₁ in the present experiment, a second CS (CS₂) was provided by a Campden Instrument Company

Fig. 6. Mean number of responses during CS₁, CS₂, and baseline (non-CS portions of session) for final five sessions of each phase of experiment for Group 3.

click generator set to deliver a train of six clicks per second at an intensity equal to CS₁.

Procedure

Preliminary training was identical to that employed in Experiment I. The treatment of three experimental groups, which differed with regard to CS-US contingency, is discussed below and summarized in Table 4. Each experi-

mental phase remained in effect for between 18 and 24 sessions. Phases were changed when baseline responding met a criterion for stability (standard deviation <10% mean responses per session) for 10 consecutive sessions.

Note that CS₁ and CS₂ refer to physically different (tone and clicker) events. The contingent relationships between CS and US were otherwise identical to those employed in Experiment I.

Table 4

Experiment II treatment of each of three groups (N=3) during five consecutive phases of 18 to 24 sessions each.

Phase	Group IV	Group V	Group VI
1	Baseline VI food schedule only		
2	CS ₁ -US-CS ₂	CS ₁ -US	CS ₁ -US-CS ₁
3	CS ₂ -US-CS ₁	CS ₂ -US-CS ₂	CS ₁ -US-CS ₂
4	CS ₁ -US-CS ₂	CS ₁ -US	CS ₁ -US-CS ₁
5	Baseline VI food schedule only		

RESULTS

The results are summarized in Tables 5 and 6 and are described below. CS ratios were computed from the same formula used in Experiment I.

Group IV

Rats in this group were exposed to a compound CS-US-CS procedure throughout Phases

Table 5
CS Ratios Obtained During Final Five Sessions of Each Phase in Experiment II

		Phase 2		Phase 3		Phase 4	
		First CS Ratio	Second CS Ratio	First CS Ratio	Second CS Ratio	First CS Ratio	Second CS Ratio
Subject							
GROUP IV							
CS ₁ -US-CS ₂	1	0.06	0.49	0.03	0.48	0.03	0.49
CS ₁ -US-CS ₂	2	0.08	0.56	0.08	0.55	0.03	0.52
CS ₁ -US-CS ₂	3	0.04	0.42	0.06	0.33	0.03	0.27
GROUP V							
CS-US	4	0.01	0.48	0.03	0.51	0.03	0.48
CS ₁ -US-CS ₂	5	0.02	0.33	0.04	0.45	0.01	0.34
CS-US	6	0.01	0.43	0.01	0.37	0.01	0.40
GROUP VI							
CS ₁ -US-CS ₁	7	0.06	0.54	0.07	0.51	0.04	0.52
CS ₁ -US-CS ₂	8	0.05	0.49	0.08	0.53	0.03	0.50
CS ₁ -US-CS ₁	9	0.08	0.51	0.03	0.44	0.02	0.52

2 to 4. The change from a physically different CS₂ to CS₁ in Phase 3 had virtually no effect on overall baseline response rates or on the degree of suppression conditioned to the first CS in the compound. Accelerated response rates were not recorded during the second CS for any subject; in fact, Subject 3, for which the lowest session response rates of the group were recorded, showed some degree of conditioned suppression to the second CS.

Group V

During Phase 2, the CS-US condition produced the lowest session response rates recorded in Experiment II. The addition of a physically different second CS in a CS₁-US-CS₂ sequence increased baseline responding for all subjects in Phase 3. Two rats showed some decrease in baseline responding when the second CS was removed in Phase 4, although not to the levels recorded in the previous phase. The responding of Subject 6 increased still further until its session rate during Phase 4 was comparable to those recorded under the CS₁-US-CS₂ conditions. All three subjects showed conditioned suppression to the first CS throughout Phases 2 to 4, regardless of which condition was in effect.

Group VI

Rats in this group were exposed to a CS-US-CS sequence throughout Phases 2 to 4. In general, baseline response rates were maintained at a high level throughout the experiment. The change to a physically different sec-

ond CS in Phase 3 produced only slight decreases in session responding for all subjects; Phase 3 baseline rates generally did not fall by more than 10% from those recorded in Phases 2 and 4. All subjects showed conditioned suppression to the first CS in the sequence, and revealed no differential effect on response rate by the second CS.

DISCUSSION

In general, the results of Experiment II replicate and extend the major findings of Experiment I. Baseline rate of responding during a conditioned-suppression procedure was substantially higher, relative to preshock baselines, when a second CS was added to the CS-US arrangement. Moreover, this general enhancement of baseline responding did not appear to depend on whether the first and second CS in the CS-US-CS arrangement were physically identical. Although rate enhancement was slightly diminished for Group VI subjects in Phase 3 following substitution of a physically different CS₂, this effect was relatively minor and might alternately be explained in terms of a more general principle such as stimulus change.

The role of the second CS within the CS-US-CS sequence is perhaps most clearly and unambiguously revealed when data for Phase 2 are examined across all groups. Groups III, IV, and VI, which were exposed to the CS-US-CS sequence, all show substantial recovery of baseline responding. This effect occurred regardless of whether the first and second CS

were physically identical (Groups III and VI versus IV). In contrast, Groups I and V, which experienced the CS-US condition, showed only partial recovery of baseline responding at the close of Phase 2.

The effect of adding a second CS to the "traditional" conditioned-suppression procedure in Group V was virtually identical to the result of this manipulation for Group I subjects in Experiment I, again despite the fact that a physically different CS₂ was employed in Experiment II. In addition to its immediate effect of raising baseline response rates, the effects of exposure to the CS₁-US-CS₂ procedure appeared to carry over to the subsequent phase, despite removal of the second CS. In no case in either Experiment I or II, did baseline rates of response return to the levels recorded before exposure to the CS-US-CS condition.

This sustained enhancement, despite removal of the CS-US-CS condition, probably reflects not only the effect of increased reinforcement resulting from elevated responding under the limited-hold contingency, but also the possibility that baseline responding tends to increase with continued exposure to the conditioned-suppression procedure (e.g., Hoffman, 1969). It is reasonable that Phase 3 exposure to the CS-US-CS condition simply accelerated the return to "normal" baseline responding, a process that would have occurred in any case, albeit more gradually (e.g., Seligman, 1968). Such an analysis presumes that other manipulations with comparable short-term effects on response rate (e.g., increasing reinforcement density on the VI schedule) might similarly maintain increased baseline responding following their removal.

It is worth noting that this analysis does not apply to the US-CS condition for Group II in Experiment I. Although temporary increases were recorded in baseline responding during exposure to a CS-US-CS condition, the re-instatement of the US-CS procedure again deteriorated baseline responding. That rate enhancement for Group II subjects should be maintained only when a CS preceded shock is reasonable from two points of view: (1) The generally suppressive effects of unsignalled shocks on baseline responding have been noted (e.g., Brimer and Kamin, 1963; Davis and McIntire, 1969; Seligman, 1968), and there is no evidence that VI responding suppressed by

unpredictable shock recovers gradually over time (e.g., Seligman and Meyer, 1970). (2) The addition of a CS before shock, which occasioned increased responding in Phase 3, directly affected "threat of the US", a far more suppressive feature of the procedure than aversion produced by conditioned stimuli.

In any case, an analysis that includes not only the probability of unconditioned aversive events (shock), but also the probability of the conditioned stimuli that signal them, seems essential for procedures such as conditioned suppression in which behavioral change is not confined to the presence of conditioned stimuli.

REFERENCES

- Annau, Z. and Kamin, L. The conditioned emotional response as a function of intensity of the US. *Journal of Comparative and Physiological Psychology*, 1961, **54**, 428-432.
- Brimer, C. and Kamin, L. Disinhibition, habituation, sensitization, and the conditioned emotional response. *Journal of Comparative and Physiological Psychology*, 1963, **56**, 508-516.
- Davis, H. Conditioned suppression: a survey of the literature. *Psychonomic Monograph Supplements*, 1968, **2**, 283-291.
- Davis, H. and McIntire, R. Conditioned suppression under positive, negative, and no contingency between conditioned and unconditioned stimuli. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 633-640.
- Davis, H., Memmott, J., and Hurwitz, H. M. B. Autocontingencies: a model for subtle behavioral control. *Journal of Experimental Psychology: General*, 1975, **104**, 169-188.
- Estes, W. K. and Skinner, B. F. Some quantitative properties of anxiety. *Journal of Experimental Psychology*, 1941, **29**, 390-400.
- Hammond, L. Increased responding to CS- in differential CER. *Psychonomic Science*, 1966, **5**, 337-338.
- Hendry, D. and Van Toller, C. Alleviation of conditioned suppression. *Journal of Comparative and Physiological Psychology*, 1965, **59**, 458-460.
- Hoffman, H. *Stimulus factors in conditioned suppression*. In B. Campbell and R. M. Church (Eds.), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969.
- Hunt, H. F. and Brady, J. V. Some effects of punishment and intercurrent "anxiety" on a simple operant. *Journal of Comparative and Physiological Psychology*, 1955, **48**, 305-310.
- Lyon, D. O. Conditioned suppression: operant variables and aversive control. *Psychological Record*, 1968, **18**, 317-338.
- Moscovitch, A. and LoLordo, V. M. Role of safety in the Pavlovian backward fear conditioning procedure. *Journal of Comparative and Physiological Psychology*, 1968, **66**, 673-678.
- Nageishi, Y. and Imada, H. Suppression of licking behavior in rats as a function of predictability of

- shock and probability of conditioned stimulus-shock pairings. *Journal of Comparative and Physiological Psychology*, 1974, 87, 1165-1173.
- Pavlov, I. P. *Conditioned reflexes*. Translated by G. V. Anrep. London: Oxford University Press, 1927.
- Ray, O. S. and Stein, L. Generalization of conditioned suppression. *Journal of the Experimental Analysis of Behavior*, 1959, 2, 357-361.
- Rescorla, R. Pavlovian conditioning and its proper control procedures. *Psychological Review*, 1967, 74, 71-80.
- Rescorla, R. Conditioned inhibition of fear resulting from negative CS-US contingencies. *Journal of Comparative and Physiological Psychology*, 1969, 67, 504-509.
- Seligman, M. E. P. Chronic fear produced by unpredictable electric shock. *Journal of Comparative and Physiological Psychology*, 1968, 72, 546-550.
- Seligman, M. E. P. and Meyer, B. Chronic fear and ulceration in rats as a function of unpredictability of safety. *Journal of Comparative and Physiological Psychology*, 1970, 73, 202-207.
- Sidman, M. and Boren, J. J. A comparison of two types of warning stimulus in an avoidance situation. *Journal of Comparative and Physiological Psychology*, 1957, 50, 282-287.

Received 6 January 1975.

(Final Acceptance 29 October 1975.)