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CONDITIONED SUPPRESSION UNDER POSITIVE, NEGATIVE, AND NO CONTINGENCY BETWEEN CONDITIONED AND UNCONDITIONED STIMULI[1]

HANK DAVIS AND ROGER W. MCINTIRE

CALIFORNIA STATE COLLEGE AT LOS ANGELES AND UNIVERSITY OF MARYLAND

Using a conditioned suppression procedure, the effects of three contingent relationships between conditioned (CS) and unconditioned (US) stimuli were investigated. A traditional positive (if CS—then US) contingency suppressed response rate during the CS relative to responding during stimulus-free minutes of the session. A negative (if CS—then no US) contingency resulted in suppressed responding during CS-off minutes, and rate increases during the CS. A no-contingency control procedure, during which CS and US were randomly related, almost totally suppressed responding throughout the session and showed no differential effects of the CS on response rate. An analysis of changes in response rate during the minute after US-offset revealed acceleration under the no-contingency condition and, to a somewhat lesser degree, under the negative contingency. Both conditioned suppression and non-suppression are analyzed in terms of the temporal relationship between CS and US.

In a recent theoretical paper, Rescorla (1967) argued that the contingency between the conditioned stimulus (CS) and unconditioned stimulus (US), rather than the pairing or simple contiguity between these two events, is a critical determinant of Pavlovian conditioning. In the language of the system proposed by Rescorla, the majority of Pavlovian conditioning research involves a positive contingency (*i.e.*, if CS—then US) stimulus arrangement and results in excitatory conditioning. A second logical arrangement of experimental events is termed the negative contingency (*i.e.*, if CS—then no US) and underlies inhibitory Pavlovian conditioning.

Rescorla argued that the appropriate control procedure for Pavlovian conditioning does not involve eliminating the US or specifically failing to pair the CS and US (*e.g.*, Thompson and McConnell, 1955; Bitterman, 1964), but rather in presenting the CS and US in random relationship to each other so that no CS-US contingency exists. Under this control procedure, CS and US may occasionally be paired on a particular trial, but such a pairing occurs strictly under a random distribution of events and predicts nothing about the order of events on subsequent trials. Furthermore, such a procedure provides a control for both excitatory and inhibitory aspects of Pavlovian conditioning.

A recent survey (Davis, 1968) of research involving the conditioned suppression or conditioned emotional response procedure of Estes and Skinner (1941) indicates that this procedure shares the emphasis on the positive contingency and excitatory conditioning typical of much Pavlovian conditioning research in this country. Conditioned suppression is frequently analyzed in terms of the elicitation of respondents (the "fear" CR) during the CS. Fear is presumed to be incompatible with the baseline operant, which is thereby suppressed (*e.g.*, Hunt and Brady, 1951; Kamin and Schaub, 1963). It is not necessary, however, to restrict the investigation of conditioned suppression to the use of a positive contingency. In fact, several recently published studies have employed what Rescorla would term a negative contingency (*i.e.*, if CS—then no US: *e.g.*, Ray and Stein, 1959; Hoffman and Fleshler, 1964; Hammond, 1966).

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Although these experimental procedures have been discussed also in terms of discrimination training, they have nonetheless allowed a partial assessment of inhibitory Pavlovian conditioning in conditioned suppression. In each of these cases, however, both an excitatory and an inhibitory CS were employed during the session, and no clear or sustained inhibition of the suppressive CR, as reflected in response rate increases during the CS, was noted. The use of a control procedure in which no contingency exists between CS and US events does not yet appear in the conditioned suppression literature.

Both the operations and descriptive language of the present experiment were derived from Rescorla's (1967) theoretical position. The experiment was specifically designed to assess the effects on operant rate of three contingent relations between CS and US events (*i.e.*, positive, negative, and no contingency). In addition, an attempt was made to study behavior in transition with the conditioned suppression procedure. To do so, the contingency conditions were changed during the experiment, which permitted also the study of some effects of prior contingency experience on subsequent performance.

METHOD

Subjects

Twenty experimentally naive rats of the Sprague-Dawley strain between 90 and 120 days old at the start of the experiment, were maintained at approximately 80% of their free-feeding body weights. (HD 41, in Group D, died during Phase 1. Cause of death was determined as hemolytic streptococcus infection.) Subjects were individually housed with water continuously available in the home cage and were fed their daily ration 30 min after each experimental session.

Apparatus

An experimental chamber 300 by 300 by 230 mm was enclosed on all sides, except the top, by a sound attenuating shell approximately 40 mm thick. A Lehigh Valley retractable lever, requiring a downward force of approximately 20 g to operate, was mounted on the left side of the rear wall. Forty-five mg Noyes pellets could be delivered into a food tray located at the center of this wall. The floor of the cage contained 18 brass grids, each 3.2 mm in diameter and mounted 12.7 mm apart. Grids were wired to a Grason Stadler shock generator and scrambler (Model E1064GS) calibrated to deliver 0.8-ma shock. The 2-sec delivery of this shock served as the US. The CS was a 1250-Hz tone, monitored at 98 db (0.0002 dynes/cm^2) at the cage speaker output. White noise monitored at 80 db within the experimental chamber was continuously present. Illumination was provided by a ceiling-mounted, unshielded 60-w bulb, located approximately 150 mm from the top of the experimental chamber.

Pretraining

All subjects were first trained with food to press the lever. After three 30-min sessions on a continuous reinforcement schedule, all animals were exposed to a variable-interval (VI) 15-sec schedule (range 3 to 45 sec) for two 30-min sessions. For the remainder of the experiment, 30-min sessions under a VI 30-sec (range 6 to 90 sec) schedule were in effect. After 30 daily sessions (six per week), and three adaptation sessions, during which the CS (tone) was presented three times per session, visual inspection of cumulative response records revealed that all animals had achieved stable response rates, *i.e.*, there were no apparent changes in the slope of individual records for several sessions; also, the CS had no differential effect on response rate. Subjects were randomly divided into five groups of four animals.

Experimental Phases

Each experimental phase consisted of 15 sessions during which three CSs and three USs were presented. US occurrences were scheduled on the basis of a random number table and occurred at the same time for all groups on a given day. (The random number table was used in the following manner: the first digit in the table determined the minute in which the first US of the session would occur; the second digit determined where in the range between minutes 10–19 the second US would occur, and the third table entry determined US occurrence in the range between minutes 20–29 of the session. Thus, if the table column read 6, 9, 2, 4, 1, 8, etc., US occurrences in Session 1 were programmed at minutes 6, 19, and 22; in Session 2 at minutes 4, 11, and 28,

etc.) Sessions were divided into thirty 1-min periods during which three CSs were presented in one of the following three relations to each US: (1) under the positive contingency, the CS immediately precedes the US and terminates with US onset; (2) under the negative contingency, no US occurs during or within 3 min of any CS; or (3) under the no-contingency control condition, the CS and US events occur independently of each other during the session; *i.e.*, CS occurrences, as well as US occurrences, are determined by a random number table.

For each experimental group, the following sequence of conditions was in effect:

Group	*Phase 1*	*Phase 2*
A	Positive contingency	No contingency
B	Negative contingency	No contingency
C	No contingency	Positive contingency
D	No contingency	Negative contingency
E	No contingency	No contingency

Data Collection and Analysis

Response frequencies were recorded for each minute of the experimental session. After each session, a CS ratio was computed by dividing the average number of responses made during each of three CS minutes by the average number of responses made during each of 24 non-event (non-CS or non-US) minutes of each session. Similarly, a US ratio was computed by dividing the average response total for the three 1-min periods after each US-offset by the average number of responses made in the 24 non-event minutes of the session. Thus, each ratio reflects responding during the CS or after the US relative to responding in all remaining minutes of the session. Ratios smaller than 1.00 indicate a decrease in response rate during this period relative to non-event minutes; ratios exceeding 1.00 reflect accelerated responding; and ratios equal or close to 1.00 indicate no differential effect of the stimulus on response rate.

RESULTS

CS Ratio

The average CS ratio for each animal in each phase of the experiment is given in Table 1.

Table 1

CS and US Ratios for Final 10 Sessions of Each Experimental Phase

Group Contengency	*Subject*	*CS Ratio*	*US Ratio*	$\bar{X}$ *Resps. /Non-Event Min.*	*Group Contingency*	*CS Ratio*	*US Ratio*	$\bar{X}$ *Resps. /Non-Event Min.*
A	HD 33	0.003	0.903	8.30	A	1.470	1.230	0.65
POS	35	0.001	0.850	18.60	NO *	0.000	4.444	0.72
	37	0.112	0.955	15.80		0.850	1.043	4.60
	38	0.121	0.666	28.70		0.000	0.083	0.48
B	HD 52	1.838	3.693	6.20	B	1.660	4.655	9.93
NEG	53	1.440	1.677	9.30	NO *	1.363	2.555	7.57
	54	++	**	0.00		++	**	0.00
	56	1.835	1.211	0.85		1.988	3.088	2.48
C	HD 30	1.180	3.181	2.20	C	0.042	1.335	35.50
NO *	36	1.040	1.086	2.30	POS	0.041	2.325	12.00
	40	0.200	0.400	0.52		0.012	0.850	46.30
	44	++	**	0.00		0.067	1.072	23.60
D	HD 34	++	++	0.01	D	++	++	0.06
NO *	42	1.220	3.838	4.09	NEG	1.144	1.955	22.10
	43	0.760	2.439	4.10		1.327	2.271	10.70
E	HD 50	1.080	1.677	3.85	E	1.000	2.593	8.25
NO *	51	1.190	1.444	3.55	NO *	1.255	1.617	6.49
	55	1.300	1.650	2.83		1.119	1.510	12.54
	57	++	++	0.08		0.978	3.767	0.49

*Corrected to exclude trials on which CS and US occurred simultaneously.

++Indeterminate ratio due to non-event rate lower than 0.10 R's/minute.

**Responding *only* in minutes following US offset.

NOTE: The response rates upon which the reported averages are based were extremely stable during the final 10 sessions of each phase. In no case did the standard deviation exceed 25% of the reported average response rate.

The reported CS ratios indicate that under the positive contingency, bar pressing was suppressed during the CS in both experimental phases (Group A–Phase 1, Group C–Phase 2). The CS did not appear to have a consistent or differential effect on response rate under the no-contingency condition. In several of the no-contingency cases (*e.g.*, HD 40, Phase 1; HD 33, 35, 38, Phase 2) interpretation of the CS ratio was questionable because responding was virtually absent throughout the session, a characteristic of the no-contingency condition. The negative contingency resulted in four cases of accelerated bar-pressing rates during the CS, three of which occurred in Group B during the first experimental phase. Illustrative cumulative response records showing the presence of the CS under all three experimental conditions are given in Fig. 1.

US Ratio

US ratios for each animal are given in Table 1, and illustrative cumulative response records that locate the US during the session are given in Fig. 2. Subjects exposed to the positive contingency during Phase 1 (Group A) showed a tendency toward reduced responding in the minute after the US (see Table 1 and Fig. 2); whereas Group C, with a history of no-contingency experience before positive contingency exposure in Phase 2, showed some tendency toward acceleration, after the US.

In comparison to subjects under other conditions, no-contingency subjects showed the greatest acceleration of responding after the US (see Table 1). With few exceptions, this occurred in both experimental phases and ranged from modified acceleration (US Ratios = 1.65, 1.67, 1.85) through marked accelerative effects (US Ratios = 3.18, 3.83, 4.65). In addition, there were instances under the no-contingency condition in which the only recorded responding occurred in the minute after US offset (HD 44 and 54).

The behavioral effects of US offset on the negative contingency subjects were strongly

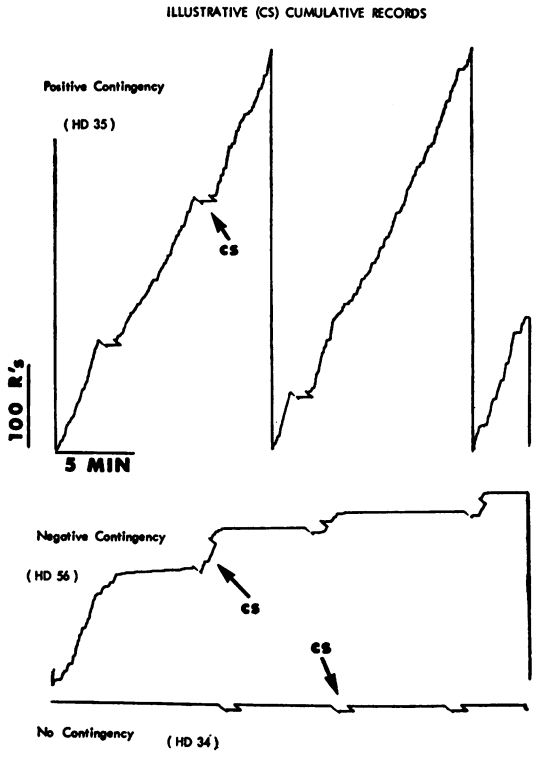

Fig. 1. Illustrative cumulative response records indicating the presence of CS (tone) events during the 30-min experimental session under positive contingency (HD 35–Phase 1), negative contingency (HD 56–Phase 1), and no contingency (HD 34–Phase 1).

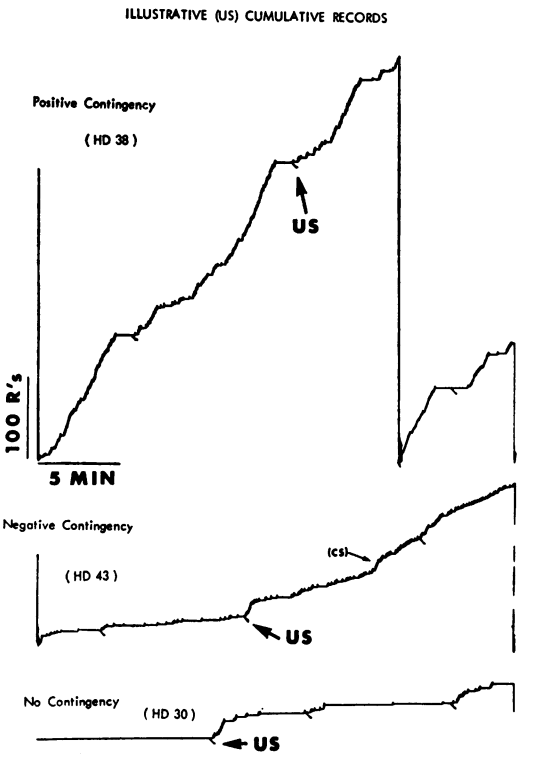

Fig. 2. Illustrative cumulative response records indicating the presence of US (shock) events during 30-min experimental session under positive contingency (HD 38–Phase 1); negative contingency (HD 43–Phase 1); and no contingency (HD 30–Phase 1).

accelerative (see Table 1). The responding of the negative contingency animal that showed least rate acceleration after US offset (HD 56) appeared to be more strongly under discriminative control of the CS (ratio = 1.835) than of the US (ratio = 1.211).

Response Rate During Non-event Minutes

The average response rate obtained during non-event minutes of the session for each subject is given in Table 1. It should be noted that non-event response rates in Phase 2 tended to be somewhat higher than in Phase 1, irrespective of experimental treatment. In general, non-event rates obtained under the positive contingency were the highest recorded in the experiment, whereas no-contingency rates were among the lowest. Negative contingency response rates overlapped both the positive and no-contingency ranges.

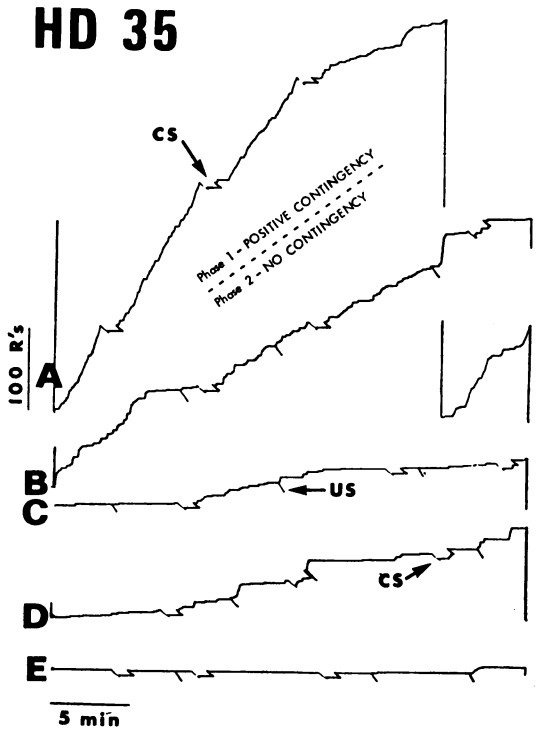

Fig. 3. Cumulative response records of HD 35 obtained during (A) final positive contingency session of Phase 1; (B) initial no-contingency session of Phase 2; (C) second no-contingency session; (D) third no-contingency session; and (E) final Phase 2 no-contingency session. Occurrence of CS (tone) and US (shock) events are noted on each cumulative response record.

Selected Transitional States and Group Comparisons

Individual data for selected groups obtained during the transition between experimental conditions are given in Table 2. In Group A, the transition between positive and no-contingency conditions produced three behavioral tendencies: (1) an attenuation of response suppression during the CS (relative to non-event rates); (2) a gradual acceleration of response rate after US-offset; and (3) a general decrease in non-event response rate. These general tendencies are illustrated in Fig. 3, which shows transitional cumulative response records obtained for Subject HD 35 of Group A.

Data from the transition from no to positive contingency by Group C is given in Table 2 as well as in Fig. 4, in which transitional cumulative response records of HD 30 are shown. These records reveal an increase in response

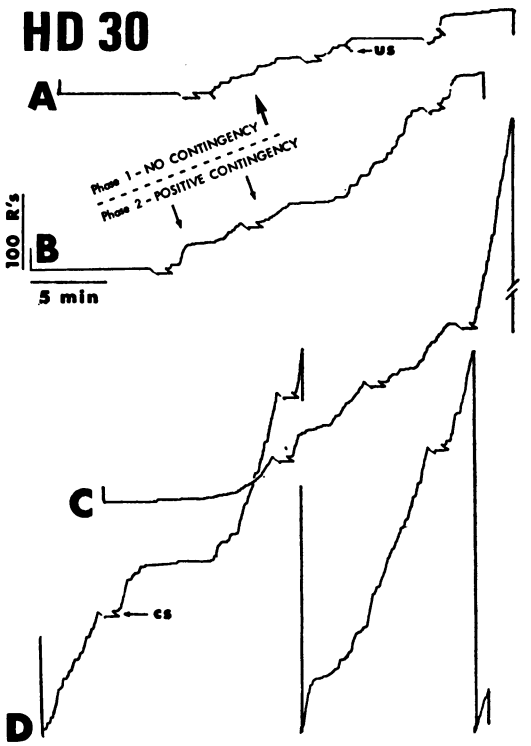

Fig. 4. Cumulative response records of HD 30 obtained during (A) final no-contingency session of Phase 1; (B) third positive-contingency session of Phase 2; (C) sixth positive-contingency session; and (D) thirteenth positive-contingency session of Phase 2. Occurrence of CS (tone) and US (shock) events are noted on each record.

Table 2

Performance of individual subjects in transition between final Phase 1 session and first five Phase 2 conditioning sessions.

Group/ Condition	Subject	Performance	Final Phase 1 Session	Phase 2 Sessions 1	2	3	4	5
Group A Pos to No Contingency	33	CS Ratio	0.000	0.050	0.110	0.345	0.750	1.125
		US Ratio	0.941	1.100	1.170	1.150	1.355	1.175
		Non-event Rate	8.50	6.20	2.10	1.60	0.80	0.75
	35	CS Ratio	0.000	0.350	0.375	0.425	0.200	0.050
		US Ratio	0.650	1.190	1.360	2.740	3.840	4.260
		Non-event Rate	20.66	10.40	2.20	3.600	1.90	1.20
	37	CS Ratio	0.084	0.125	0.207	0.573	0.640	0.809
		US Ratio	0.964	1.250	1.100	0.955	1.302	1.100
		Non-event Rate	15.66	12.60	8.25	4.25	5.56	4.10
	38	CS Ratio	0.072	0.072	0.000	0.046	0.011	0.000
		US Ratio	0.716	0.372	0.000	0.172	0.090	0.064
		Non-event Rate	32.10	19.60	8.72	6.14	1.79	0.42
Group C No to Pos Contingency	30	CS Ratio	1.138	0.972	0.407	0.263	0.110	0.052
		US Ratio	3.793	2.975	2.785	1.905	1.723	1.405
		Non-event Rate	2.90	2.95	4.33	9.45	14.65	29.20
	36	CS Ratio	0.909	0.973	0.882	0.704	0.172	0.065
		US Ratio	1.363	1.026	1.712	1.414	1.974	2.063
		Non-event Rate	2.20	2.17	4.45	3.76	8.41	9.11
	40	CS Ratio	0.589	0.460	0.174	0.060	0.084	0.033
		US Ratio	1.179	0.472	0.385	0.961	1.043	0.872
		Non-event Rate	0.57	1.19	3.57	11.62	31.20	39.75
	44	CS Ratio	—	—	0.000	0.106	0.045	0.033
		US Ratio	**	—	1.650	1.750	1.050	0.850
		Non-event Rate	0.00	0.00	0.23	3.79	14.60	22.05
Group D No to Negative Contingency	34	CS Ratio	—	—	—	—	0.00	0.00
		US Ratio	—	—	—	—	0.00	0.00
		Non-event Rate	0.00	0.00	0.00	0.00	0.12	0.08
	42	CS Ratio	0.952	1.470	1.112	1.236	1.046	1.110
		US Ratio	3.333	3.175	3.445	2.973	2.225	2.018
		Non-event Rate	4.20	5.60	7.40	16.37	14.43	18.83
	43	CS Ratio	0.811	0.845	0.997	1.110	1.250	1.265
		US Ratio	3.245	2.385	2.985	2.117	2.020	2.175
		Non-event Rate	4.93	5.06	4.58	5.95	8.22	9.13

**Responding *only* in minutes following US offset.

suppression during the CS and a general increase in non-event rate across sessions. The accelerative properties of US-offset on response rate, however, are not notably attenuated by exposure to the positive contingency.

Data for individual animals in Group D during the transition between no- and negative-contingency conditions are given in Table 2, and illustrative cumulative records from HD 43's transition are shown in Fig. 5. With the exception of HD 34, whose responding remained suppressed throughout both experimental phases, these data reveal an increase in response rate across sessions (although somewhat less than that shown for Group C), and a tendency towards response rate acceleration during the CS with continued exposure to the negative contingency.

Group E's exposure to the no-contingency condition during both experimental phases allowed assessment of the effects of prolonged exposure to CS and US events without a change in contingency condition. The data for this group indicated three general trends: (a) an increase in non-event rates for all animals; (b) a shift in CS ratios towards 1.00; *i.e.*, with increased exposure to the no-contingency condition, there was a tendency for the CS to exert no differential control on response rate; and (c) an increase in US ratios; *i.e.*, a

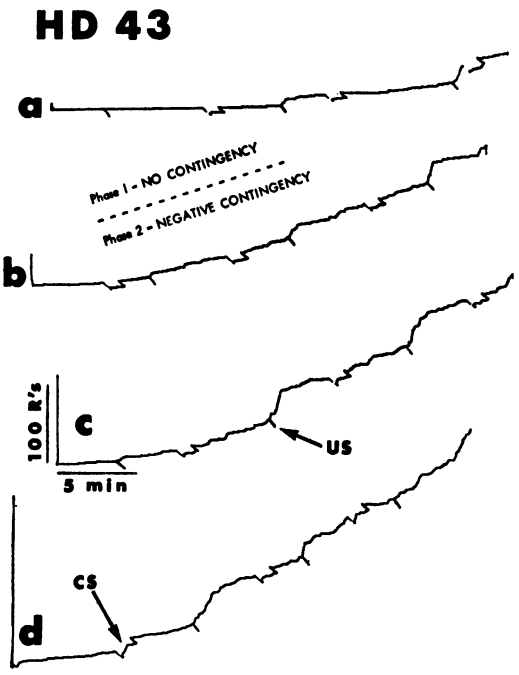

Fig. 5. Cumulative response records of HD 43 obtained during (a) final Phase 1 no-contingency session, (b) second Phase 2 session under negative CS-US contingency, (c) eighth Phase 2 negative-contingency session, and (d) final Phase 2 negative-contingency session. Occurrence of CS and US events are indicated on each response record.

tendency for the US to become a discriminative stimulus for "no shock" and to accelerate bar pressing in the period immediately after US offset.

DISCUSSION

The present positive contingency data are essentially in accord with data from the conditioned suppression literature; *i.e.*, operant response rate was suppressed during the CS upon which shock was contingent and was least affected during non-event minutes of the session. The analysis of CS-US contingency, proposed by Rescorla (1967), provides a basis in the present experiment for discussing not only suppressed responding during the CS in terms of the CS-US contingency, but also the apparent non-disruption of operant behavior during CS-off minutes of the session. By this analysis, the obverse case of the positive contingency (*i.e.*, if no CS—then no US), which also determines the conditioning process, would account for the active inhibition of suppressive respondents in the absence of the CS. Thus, just as *if CS—then US* underlies conditioned suppression, then *if no CS—then no US* underlies conditioned non-suppression in the remaining 27 min of the session.

Concerning the extensive suppression of operant rate observed under the control condition in which no CS-US contingency was scheduled, Pavlov's discussion of the "synthetic environmental reflex" may be relevant. He has written: ". . . when conditioned reflexes are being established in dogs for the first time, it is found that the whole experimental environment, beginning with the introducing of the animal into the experimental room acquires at first conditioned properties. This initial reflex could be called therefore, a conditioned reflex to the environment. But later on, when the special reflex to a single, definite and constant stimulus has appeared, all the other elements of the environment gradually lose their significance, most probably on account of a gradual development of internal inhibition." (1927, p. 115.) Thus, under the no-contingency condition, because no "definite and constant" stimulus may appear, suppression may have remained conditioned to the general environment.

It is most probable that the occasional operant rate increases after US offset (see Fig. 2) may be understood in terms of a spurious contingency which existed for all groups, but whose effects were most pronounced under the no- and negative-contingency conditions. Because no two USs were scheduled to occur in consecutive minutes, an *if US—then no US* condition may have inhibited the suppressive CR for 1-min periods immediately after US-offset. The relative absence of such rate acceleration in this period under the positive contingency may be discussed in terms of a recent analysis proposed by Seligman (1967). Whereas the negative- and no-contingency groups had few periods explicitly free from shock, the positive-contingency condition provided 27 min of "safety-signal" (absence of CS) in which the US could not occur. Thus, under the positive contingency, there was less "necessity" for such dependence on the brief period of "safety" after US-offset.

Despite the fact that the conditioned suppression procedure directly involves the experimental operations for Pavlovian conditioning, all measurement of the conditioned

response remains indirect; *i.e.*, excitatory and inhibitory conditioning effects must be inferred from the magnitude and direction of changes in operant rate. The present experiment demonstrated, however, that such changes in operant behavior may be readily produced and analyzed in terms of systematic manipulations in the contingent relationship between the CS and US.

REFERENCES

Bitterman, M. E. Classical conditioning in the goldfish as a function of the CS-US interval. *Journal of Comparative and Physiological Psychology*, 1964, **58**, 359-366.

Davis, H. Conditioned suppression: A survey of the literature. *Psychonomic Monograph Supplements*, **2**, *No. 14 (Whole No. 30)*, 283-291.

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.

Hoffman, H. and Fleshler, M. Stimulus aspects of aversive controls: stimulus generalization of conditioned suppression following discrimination training. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 233-239.

Hunt, H. and Brady, J. Some effects of electro-convulsive shock on a conditioned emotional response ("anxiety"). *Journal of Comparative and Physiological Psychology*, 1951, **44**, 88-98.

Kamin, L. and Schaub, R. Effects of conditioned stimulus intensity on the conditioned emotional response. *Journal of Comparative and Physiological Psychology*, 1963, **56**, 502-507.

Pavlov, I. P. *Conditioned reflexes.* Translated by G. V. Anrep. London: Oxford University Press, 1927.

Ray, O. 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.

Seligman, M. E. P. *Chronic fear produced by unpredictable electric shock.* Paper presented at a meeting of the Psychonomic Society, Chicago, Ill., 1967.

Thompson, R. and McConnell, J. Classical conditioning in the planarian, *Dugesia dorotocephala*. *Journal of Comparative and Physiological Psychology*, 1955, **48**, 65-68.

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