

# CONDITIONED SUPPRESSION WITH NO CS-US CONTINGENCY IN THE RAT\*

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## ABSTRACT

CSs were presented to rats licking sucrose after one of several off-the-baseline Pavlovian defense conditioning procedures. Two random procedures in which there was no CS-US contingency were constructed by programming CSs and USs on independent random schedules which had either a long or a short variable inter-CS interval (VITI). Because the CS took up more of the session in the short VITI procedure, it contained more CS-US pairings and produced CS-elicited suppression of licking. Suppression occurred with neither the long VITI group nor with shock alone controls. Conditioning was all-or-none after both classical and random procedures.

ACCORDING TO THE CONTINGENCY THEORY of classical conditioning, excitatory conditioning occurs when the probability of an unconditional stimulus (US) given a conditional stimulus (CS) is greater than the probability of a US given no CS, per unit time. Inhibitory conditioning results when the probability of a US given a CS is less than the probability of a US given no CS. The logical control for these excitatory and inhibitory processes is the truly random procedure in which the probability of a US is the same in the presence and the absence of the CS. Rescorla (1967) has argued that, from a contingency point of view, the truly random procedure is the only appropriate control for nonassociative effects in classical conditioning because only it is identical to the classical conditioning procedure in all respects save the contingency.

Rescorla (1968, 1969) has found support for his position in several experiments employing an off-the-baseline CER (conditioned emotional response) procedure. An off-the-baseline procedure is one in which classical conditioning occurs while the animal is not engaged in the behavior to be affected by the CS (the baseline response). In Rescorla's experiment, where shock was programmed to be equiprobable through a session, the

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CS did not suppress variable interval (VI) responding for food in rats; however, the higher the probability of shock during the CS in relation to the probability of shock in its absence, the greater the suppressive properties that the CS acquired. In the reverse case, the higher the shock density in the absence of the CS when no shocks were programmed in its presence, the greater the inhibitory properties the CS acquired.

The random control procedure has increased in popularity since Rescorla's 1967 paper but despite its widespread acceptance, it has not gone uncriticized. Grossen and Bolles (1968), using a free operant (Sidman) shuttle avoidance schedule to obtain a baseline response, found that an off-the-baseline random procedure produced considerably more variability than a shock alone procedure, and decided on this practical basis that the shock alone control was more appropriate. Further criticism has come from Seligman (1969) who, using an on-the-baseline conditioned suppression method with rats, has found that the random control produces much more baseline suppression than a classical conditioning procedure. This difference in baselines between the random and classical groups made it impossible to assess the relative amount of behavioral control the CS had over the groups' behavior. Seligman discovered, in addition, that the stomachs of subjects in his random control group became ulcerated whereas those of subjects in the classical conditioning group did not.

We have seen that the random procedure has been criticized on practical grounds; it may also be thought inadequate on theoretical grounds if one considers that the important factor in classical conditioning is the contiguity between CS and US. Kremer and Kamin (1969) have attempted to show that associative processes are occurring in the random control due to the chance CS-US pairings that occur. In one experiment they examined the role of CS onset in the random procedure. CS onset has been shown to be a critical parameter in CER acquisition (Kamin, 1965). In this experiment 2 min or 15 min of white noise alternated with equal intervals of silence during five off-the-baseline sessions in which shock occurrence was equiprobable. The hooded rats then recovered their VI baselines in either white noise or silence and were later tested with either 2 min of noise or silence, depending on their recovery condition. Little suppression was elicited by the 2-min silence in testing; however, in testing with the noise, more suppression was found in the 2-min than in the 15-min cycle group. This finding supports a contiguity position since more suppression was obtained when there was more contiguity between CS onset and shock, all else being equal.

It is apparent that CS-elicited behavioral changes are sometimes observed with the truly random procedure and sometimes not. One variable

which may account for this discrepancy is the proportion of each acquisition session that is taken up by the cs. According to contiguity theory this variable should be of importance because as the ratio of cs-on time to cs-off time increases, the number of chance cs-us pairings also increases.

In studies where suppression was obtained with the noncontingent procedure, the total cs-on time constituted a large portion of the acquisition session - i.e. long css and/or short inter-cs intervals were employed, and where it was not obtained the cs took up only a small portion of the session. For example, in Kremer and Kamin's work the cs was on for  $\frac{1}{4}$  and  $\frac{1}{2}$  of the acquisition session in different experiments. In Rescorla's experiments the total cs-on time typically constituted  $\frac{1}{4}$  of the session and no suppression to the cs was observed. Similarly, we have found no suppression with the random procedure where the cs occupied approximately  $\frac{1}{4}$  of the acquisition session (Quinsey & Ayres, 1969).

#### EXPERIMENT I

The purpose of Experiment I was to assess the role of relative cs-on time in the truly random procedure while adding a traditional control for non-associative effects, a shock alone group.

#### *Method*

*Subjects.* The subjects were 48 naive, male, albino, Sprague Dawley rats that arrived in the laboratory from Gofmoor Farms, Westboro, Massachusetts when they were approximately 80 days old. They were gradually reduced to, and maintained at, 80 per cent of their free feeding body weight during the week prior to the experiment.

*Apparatus.* Six Model c Gerbrands' operant chambers with dipper feeders were contained in plywood cubes lined with acoustical tile. Continuous white noise of 90 db intensity was presented through a speaker on the chamber lid. The cs consisted of the simultaneous offset of the white noise and onset of a 1000-Hz, 84-db tone. Sound intensity was measured inside the testing chamber with the ventilating fans on. Scrambled shock was provided by six Grason Stadler shock sources (Model  $\kappa$ 1064). Standard programming equipment controlled experimental events from an adjacent room.

A 32 per cent (weight/weight) sucrose solution was available to subject in 0.1 cc dipper cups for the first 3 sec in every 5-sec period throughout each session in which the animals were allowed to lick. No sucrose was available to the subject in sessions where shock was delivered. Dipper licking was recorded on print out counters and cumulative recorders.

*Procedure.* The study consisted of ten daily sessions. A brief dipper training procedure preceded the first session by one day. The first two sessions, which were 15 min long, contained 1-min cs presentations in the 6th and 11th min and served to habituate the rats to the cs.

Two cs/us random sessions followed. Animals were arbitrarily assigned to four equal groups which differed in their treatment on the two defense conditioning days.

The between-subjects design was a  $2 \times 2$  factorial where the variables were (a) the presence or absence of a cs and (b) a 10- or 60-sec *VITI*. The "viti" in the cs-absent condition is figurative since there were no tones to be separated but cs presence or absence did not affect session length. The four groups were designated P-S (cs-present, short *VITI*), A-L (cs-absent, long *VITI*), A-S, and P-L.

The 10-sec *VITI*, which separated the 20-sec cs's, varied from 2 to 18 sec and the 60-sec *VITIs* were obtained from these by multiplying each *VITI* by six. There were 20 cs's in each acquisition session. The presentation times of the 20, 1-sec, 3-ma shocks that occurred in each acquisition session were obtained from a table of random numbers. The same distribution of shocks was given to each cs-present group and its corresponding cs-absent control. The animals in each group were run six at a time, each run having a different sequence of cs and us presentations. A different sequence was programmed in each acquisition session. Care was taken to ensure that the probability of a us given a cs per unit time was not greater than the probability of a us given no cs in the cs-present groups; this was accomplished by only accepting programming tapes in which the proportion of us's occurring during the cs approximately equalled the proportion of the session for which the cs was on. In Group P-S, both the probability of a us given a cs and the probability of a us given no cs per 20-sec interval were approximately 0.65; in Group P-L these values were approximately 0.25.

Defense conditioning was followed by a recovery-of-licking session in which each subject met a criterion of 300 licks within one 15-min session. If subject failed to meet the criterion in the first 15-min session, the procedure was repeated until he did. Subjects were removed from the apparatus after the criterion was met. It took 2 days for all subjects to reach the criterion.

Four extinction sessions, identical to the habituation sessions, completed the experiment. Habituation and extinction sessions are termed pretest and test sessions, respectively.

*Treatment of the data.* The raw data were converted to suppression ratios,  $D/(B+D)$ , where  $D$  represents the number of responses during the cs and  $B$  the number of responses in an equal period of time immediately preceding it. In the rare instance, where a subject did not respond in the presence or absence of the cs he was assigned a suppression ratio of zero if his first suppression ratio was zero when he began to respond; otherwise he was assigned the mean of his group for that cs presentation. The suppression ratio data were analyzed in two,  $2 \times 2$  analyses of variance with Days and cs-presentations as the within-S variables. The first included the second habituation session and the first extinction session while the second covered all four extinction sessions. Many of the  $F$  values reported, however, are from planned contrasts performed subsequent to the overall analyses. Licks per minute for the first 5 min of each extinction session were analyzed in a  $2 \times 2$  analysis of variance with Days as the within-S variable. In addition, cumulative records of licks per 20-sec intervals were obtained for each subject starting 20 sec before and ending 20 sec after each cs. Latency to 300 licks was recorded in the recovery session.

## Results

The suppression ratio data, shown in Figure 1, indicated that shock alone had no effect on suppression to the cs. Only Group P-S suppressed significantly more in the first extinction session than in the last habituation day ( $F = 6.98$ ,  $df = 1/44$ ,  $p < 0.025$ ). On the first extinction day,

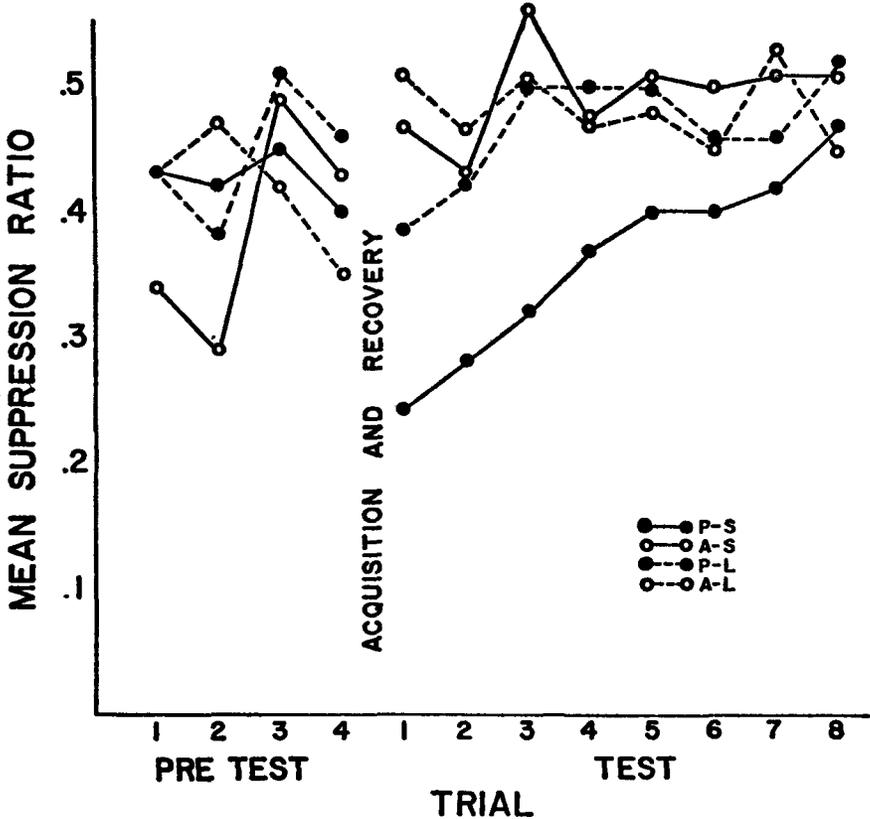


FIGURE 1. Mean suppression ratios as a function of test trials in Experiment 1.

Group P-S suppressed more than Group P-L ( $F = 6.13$ ,  $df = 1/44$ ,  $p < 0.025$ ), reflecting an effect of relative CS-on time, and Group A-S ( $F = 9.83$ ,  $df = 1/44$ ,  $p < 0.005$ ). The difference between P-L and A-L was not reliable. Averaging over all groups, suppression extinguished over days ( $F = 4.92$ ,  $df = 3/132$ ,  $p < 0.005$ ).

Lick rate increased over the first five minutes of each extinction session ( $p < 0.001$ ) and over extinction sessions ( $p < 0.001$ ). The increase in response rate over minutes was more marked in the short VTR groups than in the long:  $F = 4.37$ ,  $df = 4/176$ ,  $p < 0.005$  for the VTR Duration  $\times$  Minute Interaction. The overall response rate of the short VTR groups was also lower than the long VTR groups in extinction ( $p < 0.025$ ). Most importantly, there was no reliable difference in response rate between Group P-S, which suppressed to the CS and Group A-S which did not.

There were no significant group differences on the recovery latency measure, although the trend was similar to that reported for the response

rate data. Individual cumulative records showed that most animals recovered in an all-or-none manner in that their response rate remained relatively constant from the first to the 300th lick.

### *Discussion*

The number of cs-us pairings appear to determine the amount of suppression that the cs will elicit in the absence of a cs-us contingency. This inference is drawn because Group P-s suppressed more than Group P-L, which received fewer cs-us pairings, and Group A-s in which there were none, even though there was no cs-us contingency in either of the random groups. If the suppression observed in Group P-s is due to nonassociative processes, they are of a special kind. No suppression is observed when high intensity shocks but no cses are given in a short session and no suppression is observed when shocks and cses are given in a longer session. In addition, pilot data (Quinsey, 1970) from a within-S experiment tentatively suggest that varying cs duration while holding session length constant is equivalent to holding cs duration constant while varying session length as was done in this study.

It is somewhat surprising that response rate in the beginning of each extinction session was more suppressed in the groups that had the shorter acquisition sessions. If baseline suppression is due to classical conditioning of fear to the apparatus cues via contiguity, then the groups that had no cses in acquisition should show the most suppression to the apparatus cues, not the groups with the shortest acquisition sessions. In fact, more apparatus cue-shock pairings (in the absence of the cs) occurred in Group P-L than in Group P-s.

## EXPERIMENT II

Experiment II was designed to compare a traditional classical conditioning procedure to the truly random control at two levels of shock intensity. High shock intensity was hypothesized to be a necessary condition for obtaining cs-elicited suppression after a cs/us random procedure because it should increase the generalization between the cs and apparatus cues and enhance the value of chance pairings that occur. This experiment also afforded opportunity to compare the pattern of suppression during the cs in the classical and random groups. It would be of considerable interest if subjects from the random control group could be differentiated from those in the classical conditioning group on the basis of their pattern of suppression during the cs.

### *Method*

*Subjects and Apparatus.* The subjects were 48 rats similar to those in Experiment I. One rat failed to respond after acquisition and another was lost due to experimental

error, so two further animals were chosen randomly and discarded to make 11 rats in each group. The apparatus was unchanged as were the pre-experimental procedures.

*Procedure.* Habituation, recovery and extinction sessions were identical to those in Experiment I, except that recovery was completed in one day. For the two acquisition sessions, the groups were arranged in a  $2 \times 2$  factorial where the variables were: (a) 0.8 or 3.0-ma shock intensity and (b) classical or cs/us random procedure. The groups were designated: C-L (classical, low shock intensity), R-H (random, high shock intensity), C-H, and R-L. In each acquisition session there were 20, 20-sec tone ccs and 20, 1-sec uss. All groups received the same sequence of ccs. The us occurred in the last second of each cs for Groups C-H and C-L, whereas it had no fixed relation to the cs in the random groups. Group R-H was a replication of Group P-S in Experiment I, as was Group R-L except for the lower shock intensity.

### Results

The suppression ratio data are presented in Figure 2. Groups C-H, C-L, and R-H suppressed more to the first cs presentation of extinction than the

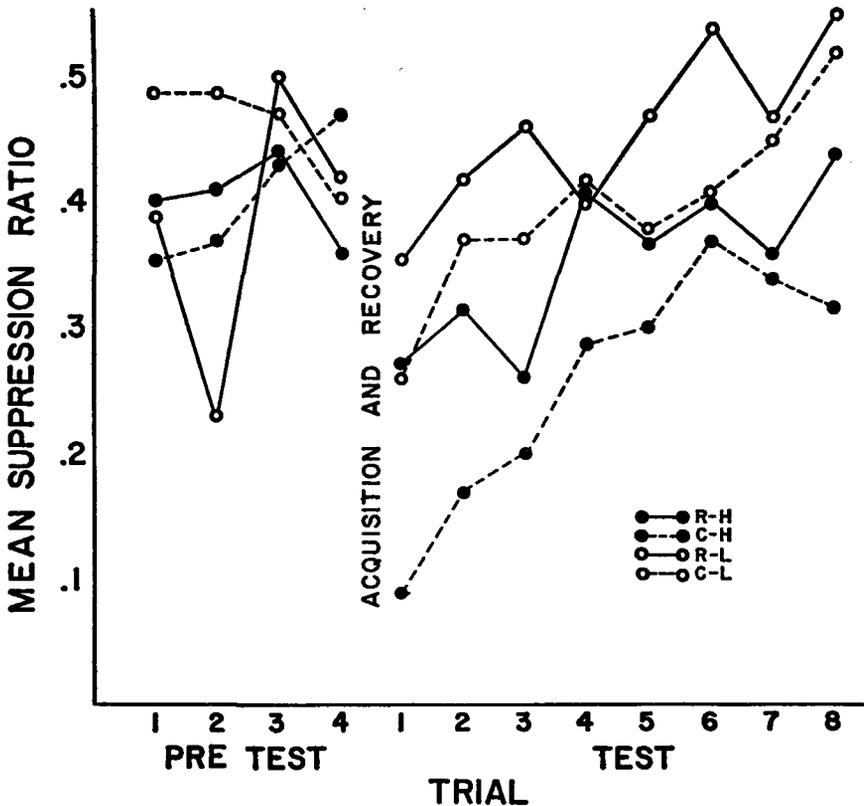


FIGURE 2. Mean suppression ratios as a function of test trials in Experiment II.

corresponding cs on Habituation Day 2 (all  $p$ 's  $< 0.05$ ) but Group R-L did not ( $F = 3.81$ ,  $df = 1/40$ ,  $p < 0.10$ ).

Shock intensity affected the amount of cs-elicited suppression shown on the first extinction day. The 3.0-ma shock produced more suppression in the classical conditioning paradigm ( $F = 7.81$ ,  $df = 1/40$ ,  $p < 0.01$ ) and in the random condition. This latter contrast was not reliable over the first two cs presentations but was over the first three ( $F = 5.46$ ,  $df = 1/40$ ,  $p < 0.025$ ).

Number of cs-US pairings and/or cs-US contingency was an important variable. Group C-H suppressed more to the cs on the first extinction session than Group R-H ( $F = 5.70$ ,  $df = 1/40$ ,  $p < 0.05$ ) but this contrast was not reliable between the low intensity groups.

Examination of individual cumulative records revealed that subjects fell into two distinct clusters: those who made only a few, or no responses during the first cs in extinction and those who showed no rate change when the cs came on. Out of the 56 subjects in Groups C-H, C-L, R-L, R-H, and P-S, there were only four that could be judged "intermediates." The differences between groups occurred, therefore, primarily because of differences in the proportion of subjects who conditioned - for example, nine rats suppressed in Group C-H but only five in Group R-H. Within Groups R-H and P-S, conditioners and non-conditioners did not differ significantly in number of responses in the minute preceding the cs ( $p > 0.10$  with a two-tailed Wilcoxon Rank Sum test). Extinction, however, was not all-or-none; subjects sometimes showed a gradual increase in lick rate over cs presentations and sometimes an abrupt recovery within or between cs's.

Among subjects who conditioned in the high shock intensity groups, R-H subjects continued to suppress in the minute following the first cs more than C-H rats ( $p < 0.05$  with a two-tailed Wilcoxon Rank Sum test). It is reasonable that animals receiving a cs/US random sequence should show more post-cs suppression than rats experiencing a classical procedure since the post-cs interval was always shock-free for the latter but was not for the former.

The high shock groups took longer to reach the recovery criterion ( $F = 9.41$ ,  $df = 1/40$ ,  $p < 0.005$ ) but shock intensity did not affect response rate in extinction. As in Experiment 1, lick rate increased over the first 5 min of each extinction session ( $p < 0.001$ ) and over sessions ( $p < 0.001$ ). There was a significant Contingency  $\times$  Minutes  $\times$  Days Interaction ( $F = 3.25$ ,  $df = 8/320$ ,  $p < 0.005$ ) which reflected the great suppression of licking and fast recovery exhibited by the truly random groups over the first 5 min of the first extinction session. Non-cs cues, therefore, exerted more control over the behavior of the random groups

than over that of the classical groups although this effect was not reliable in the latency measure.

### *Discussion*

The results were much as expected: the classical conditioning procedure and the high shock intensity produced more suppression to the cs. The extinction curve of Group R-H resembled that of the group in Experiment I which had received the same treatment, Group P-S.

One interesting aspect of these data is the apparent all-or-none conditioning. The CER paradigm used in these studies appears to be maximally sensitive to individual differences, since in the high shock random groups and Group C-L approximately 50 per cent of the rats conditioned, most of the others showing no change in behavior during the cs. It is not clear what causes this bimodal split. This distribution of suppression ratios in testing does not imply that the conditioning process in individual animals is discontinuous. It could be that acquisition was gradual but that all subjects that were affected had reached asymptote before testing began.

### EXPERIMENT III

Experiment III was designed to determine if rats can form the conditional discrimination "if dipper then no shock" over successive off-the-baseline acquisitions. This question is of interest since subjects were never shocked in the presence of the dipper in any of the present experiments. More important theoretically, it was designed to show whether the course of this discrimination differs between the truly random and classical conditioning procedures. According to contingency theory, the rats receiving the truly random procedure have another discrimination to form, they must discriminate that there is no CS-US contingency. Programming CSs and USs independently of each other does not guarantee that animals will detect this independence (Rescorla, 1967). It could be argued that under the massed CS-US presentations of these experiments, animals need many acquisition sessions to behave as if there were no consistent relation between the CS and US. If this reasoning is accepted then suppression in the truly random group should disappear faster than in a classical group over successive acquisition-extinction cycles.

### *Method*

*Subjects.* Groups C-H and R-H of Experiment II were used. One rat died in Group R-H so another was chosen randomly from C-H and discarded, making 10 subjects per group.

*Procedure.* After the fourth extinction session of Experiment I another two acqui-

tion sessions identical to the first two were given. Note that with shocks of 3.0-ma intensity and intervals of several days between successive series, it is highly unlikely that significant habituation would occur. Recovery and extinction sessions followed as before. The same procedure was then repeated twice more. Extinction was carried out until the mean suppression ratios of both groups were above 0.35 on the first extinction and 0.45 on the remaining three. In no case was there a significant difference between groups on the last extinction session.

### Results

As can be seen in the upper panel of Figure 3, suppression was attenuated over successive extinctions. An analysis of variance on the first extinction session of each replication yielded a significant replication effect ( $F = 14.34$ ,  $df = 3/54$ ,  $p < 0.001$ ). Over the first two replications, Group C-H suppressed more than Group R-H ( $F = 7.52$ ,  $df = 1/18$ ,  $p < 0.025$ ). Subjects also recovered faster with each recovery session ( $F = 26.22$ ,  $df = 3/54$ ,  $p < 0.001$ ). The lower panel of Figure 3 shows that the decrease in latency followed a similar course to the decrease in CS-elicited suppression. Group C-H recovered faster than Group R-H in the first two replications ( $F = 8.45$ ,  $df = 1/18$ ,  $p < 0.01$ ). There was a negative relationship between suppression to the apparatus cues and suppression to the CS, since Group R-H showed both longer latency to recover and less suppression to the CS than Group C-H. This inverse relation between suppression to apparatus cues and CS-elicited suppression has also been found by Dweck and Wagner (1970).

Subjects who suppressed to the CS in the first replication tended to suppress in the second. The product moment correlation between the mean suppression ratios of the first session of the first replication and that of the second replication was 0.676 ( $p < 0.003$ ). The same held true for the latency to recovery in the first two replications ( $r = 0.516$ ,  $p < 0.008$ ). There was a negative, although not significant, relationship between subjects' suppression ratios and recovery latencies in the first replication ( $-r = 0.320$ ,  $p < 0.10$ ).

### DISCUSSION

In every case where us number, intensity, and duration were constant, the proportion of subjects suppressing increased with the number of CS-US pairings. In order of increasing suppression to the CS, the relevant conditions are: US alone, CS/US random with long VIII, CS/US random with short VIII, and US at the end of each CS. Although the random long VIII and the US alone group were not significantly different, the difference was in the right direction. In the first case, the US-alone control, it is unclear whether there is a negative CS-US contingency or not. The contingency is

not negative within a session since the session contains no shock free ccs but does appear to be negative over sessions, because ccs in habituation and extinction contain no uss. Since, in neither of the random conditions does the cs predict the us, only the classical procedure provides a positive

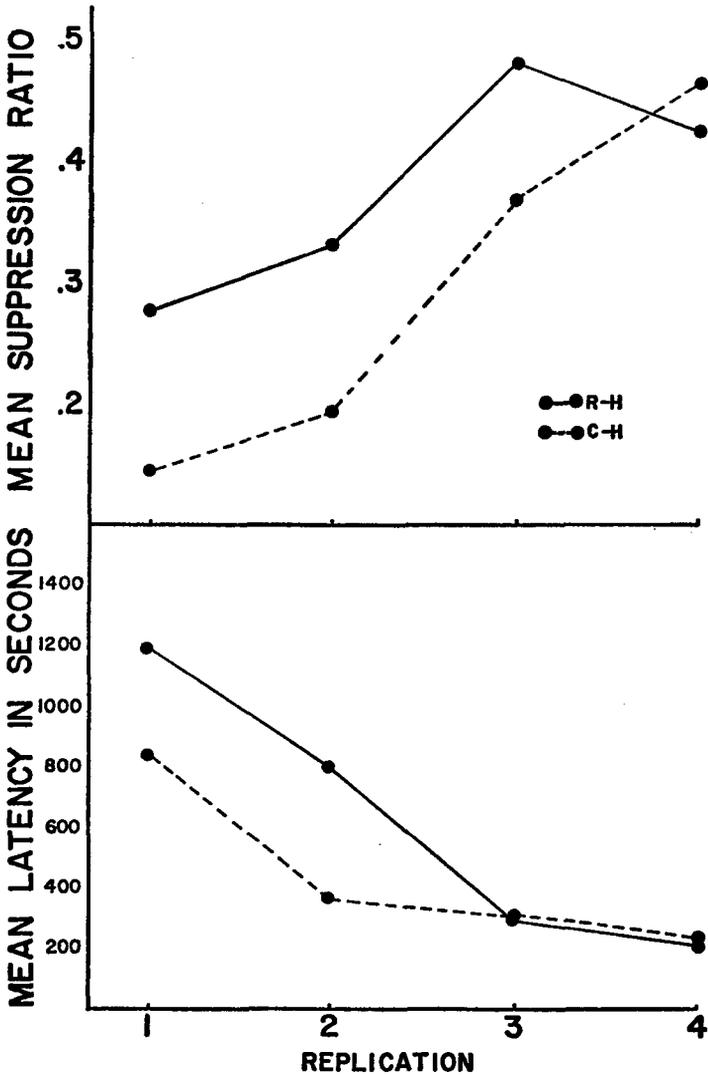


FIGURE 3. Upper Panel: Mean suppression ratios as a function of first extinction session in each replication. Lower Panel: Mean latency to 300 licks as a function of recovery replications.

contingency between these events. Contingency theory predicts conditioning, therefore, only in the classical group. Since conditioning occurred in the cs/us random condition only when there were frequent cs-us pairings, contiguity theory is supported against contingency theory.

Suppression in the random groups did not appear to be due to non-associative factors because there was no effect of shock alone presentations or shock and cs presentations with infrequent pairings. Furthermore, the parameters that affect the amount of suppression obtained with the classical conditioning paradigm, such as shock intensity and number of successive off-the-baseline acquisitions, similarly affected suppression in the truly random procedure. The all-or-none pattern of suppression to the cs was also alike in the two groups. The weight of these data, taken in conjunction with those of Kremer and Kamin, strongly suggest that changes in behavior produced by the cs/us random procedure with massed cs presentations are due to classical conditioning and that this conditioning is dependent on cs-us contiguity.

This conclusion in favor of contiguity theory, although certainly plausible, does not preclude others because of the following considerations. The cs in these studies was less intense than the white masking noise it replaced; in addition, the white noise was on for less time than the cs in the massed acquisition conditions. These considerations make the white noise appear more like the cs in conventional classical conditioning studies. The only thing that made the tone the cs, was that it was discretely presented in habituation and extinction, whereas the white noise was on continuously, allowing fear elicited by it to extinguish, as seen in recovery sessions. Thus, an altered contingency view can still be defended as follows: in the random procedure with massed cses there was a higher probability of shock in the conditioning situation than in the home cage and, therefore, fear was conditioned to the conditioning situation. Fear was extinguished to some of the conditioning situation cues in recovery and extinction and subsequently the unextinguished fear elicited by the cs was measured by comparing behavior during the cs to behavior during non-cs periods where fear had been extinguished. The logical random control procedure, according to this view, would entail having shocks occur randomly throughout a 24-hr day.

Since the completion of these experiments, Rescorla and Wagner (1969) have expanded contingency theory so it predicts that the cs will acquire the ability to suppress responding early in acquisition under certain conditions. According to the model, the cs should not suppress responding at asymptote. Three variables are supposed to be responsible for the cs coming to suppress responding preasymptotically: (a) high overall probability of shock, (b) large proportion of the session in which

the cs is present, and (c) high salience of the cs relative to the background stimuli.

Although it is tempting to reinterpret the present studies in terms of this contingency theory, it is not clear whether or not the altered model handles these data. The first two of the three variables hypothesized by Rescorla and Wagner to be necessary for preasymptotic cs-elicited suppression are present in the random groups of this experiment but the third is not. The tone cs in the present studies was less intense than the background noise it replaced. In addition, there is no way of knowing whether or not conditioning was asymptotic in these studies. Experiments obtaining obviously preasymptotic data from random control groups will be necessary to decide between contiguity and the expanded contingency theory. Regardless of these theoretical issues, however, the practical difficulty with the random control remains. Large variability may result when there are cs-us pairings and some animals condition.

### RÉSUMÉ

Présentation de stimuli conditionnels à des rats occupés à lécher du sucrose après l'une de plusieurs techniques de conditionnement défensif (pavlovien) de type hors-circuit. Deux techniques aléatoires, sans contingence cs-us, sont construites selon une programmation de cs et de us en séances indépendantes aléatoires comportant un intervalle inter-cs variable (VITI) de courte ou de longue durée. Du fait que le cs agit plus longtemps dans la technique VITI de courte durée, les couplages cs-us sont plus nombreux et l'on observe une suppression du lèchement élicité par le cs. La suppression ne s'observe pas dans le groupe VITI de longue durée ni chez les sujets de contrôle soumis seulement à un choc. Le conditionnement est de type tout-ou-rien dans la technique classique comme dans la technique aléatoire.

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