

# The effects of separate presentations of the US on conditioned suppression

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Four experiments examined the effects of separate presentations of shock on conditioned suppression of instrumental responding evoked by a CS previously paired with shock. Experiment 1 showed that conditioned suppression of responding resulting from noise-shock pairings increased as a function of time after the initial noise-shock pairings. However, it also showed that this time-dependent increase in conditioned suppression of responding could be attenuated by presentations of light-shock pairings immediately prior to the test of the noise CS. Experiment 2 showed that this attenuation effect can be produced by presentations of either light-shock pairings or shock alone. Experiment 3 showed that the magnitude of this attenuation effect was directly related to the temporal proximity of the light-shock pairings to the test of the noise CS. Experiment 4 showed that the magnitude of this attenuation effect was inversely related to the intensity of separate shock presentations.

In many Pavlovian conditioning settings, separate presentation of the unconditioned stimulus (US) affects the performance of a first-order conditioned response (CR) established through pairings of a conditioned stimulus (CS) and US. Normal acquisition of a first-order CR is decremented when the organism receives a single presentation of the US either immediately prior to or immediately following a pairing of the CS and US (Best & Domjan, 1979; Domjan, 1977, 1978; Domjan & Best, 1977; Terry, 1976; Wagner, Rudy, & Whitlow, 1973). Similar deficits in the acquisition of a first-order CR occur following repeated presentations of the US, even when those presentations are temporally quite distant from pairings of CS and US (cf. Randich & LoLordo, 1979a). These decremental effects of separate presentation of the US on Pavlovian conditioning have been discussed within the framework of a variety of theories, including opponent-process aftereffects (Solomon & Corbit, 1974), priming of short-term memory (Wagner, 1976), changing the organism's memory of the US (Rescorla, 1974), and conditioning of situational stimuli (Rescorla & Wagner, 1972).

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The present series of experiments considered the possibility of a related effect of separate presentation of the US: that it temporarily decrements performance of the first-order CR to a previously conditioned stimulus (Colby & Smith, 1978; Rescorla, 1973). However, our specific concern with this possibility arose initially from an observation frequently made during the course of an experiment on conditioned suppression of instrumental responding—that a substantial increase in conditioned suppression occurs between the last conditioning trial of the first session and the first conditioning trial of the second session, that is, an incubation effect (McMichael, 1966). Studies of the effects of separate presentation of the US suggest the possibility that, during the initial conditioning session, US presentations occurring in the context of CS-US pairings may act to decrement performance of the first-order CR, and that the between-sessions increase in conditioned suppression may simply represent a dissipation of that decremental effect of US presentation. In other words, incubation of conditioned suppression may not be due to a time-dependent increase in the strength of the CS-US association, but rather to a time-dependent loss of some decremental effect of US presentation. This view can be evaluated by exposing the organism to separate presentations of the US between initial conditioning and testing of a CS. Disruption of incubation of conditioned suppression would suggest that it is mediated by factors related to US occurrence rather than to changes in the CS-US association.

Experiment 1 replicated the finding of McMichael (1966) that conditioned suppression increases as a function of time since the initial pairings of CS and US, but also showed that this increase can be attenuated by separate presentations of the US immediately prior to the test of the CS. Experiments 2-4 examined variables that contribute to the effects of separate presentations of the US in attenuating conditioned suppression, including (1) the presence or absence of a discrete signal for separate US presentations, (2) the temporal proximity of separate US presentations to the test of the CS, and (3) the intensity of separate US presentations.

## EXPERIMENT 1

McMichael (1966) showed that conditioned suppression monotonically increased as a function of time since the initial pairings of CS and US. Experiment 1 attempted to replicate this incubation phenomenon and to determine whether it can be disrupted by separate presentations of the US.

### Method

**Subjects.** The subjects were 24 male Sprague-Dawley rats about 90 days old at the start of the experiment. They were maintained at 80% of their free-feeding weights throughout the experiment. There were eight subjects per group.

**Apparatus.** The apparatus consisted of eight identical operant chambers (measuring 22.9 × 20.3 × 20.3 cm) enclosed in sound- and light-attenuating shells. The response lever was located to the left of a recessed food magazine. The floor of the chamber was composed of .49-cm stainless steel rods spaced 1.9 cm apart. The grid could be electrified through a relay-sequence scrambler from a high-voltage high-resistance shock source. The two end walls of the chamber were aluminum; the side walls and top were clear Plexiglas. The visual CS was a 6-W houselight. The auditory CS was a white noise stimulus measuring 80 dB re  $\mu\text{N}/\text{m}^2$  against a background level of 62 dB.

**Procedure.** In the first session, all rats were magazine-trained automatically with food pellets (Noyes, 45 mg) delivered on a variable-time 1-min schedule. Each barpress also yielded an additional food pellet. This session continued until the rat emitted about 50 barpresses. Starting on the second experimental day, all sessions were 1.5 h in duration, and the rats responded for food-reinforcers on a variable-interval 1-min (VI 1-min) schedule. VI 1-min training continued for seven sessions.

In the first conditioning session, all groups received two presentations of a 3-min noise stimulus that terminated with a .5-sec .5-mA electric shock. The intertrial interval (ITI) was 12 min. Noise-shock pairings were superimposed on the baseline maintained by the VI 1-min schedule of reinforcement.

One group of rats then received four nonreinforced presentations of the 3-min noise stimulus immediately following those conditioning trials. Nine minutes elapsed between the second noise-conditioning trial and the first noise-extinction test. The mean ITI for the remaining noise-extinction trials was 9 min. This group is denoted as Group I (immediate test). The remaining two groups of rats also received the same schedule of nonreinforced presentations of the 3-min noise stimulus, but these were administered 24 h after the initial conditioning trials. In addition, one of those groups received two additional presentations of a 3-min light stimulus that terminated with a .5-sec .5-mA electric shock immediately prior to the first noise-extinction test. Light-shock trials were spaced 12 min apart, and 9 min elapsed between the second

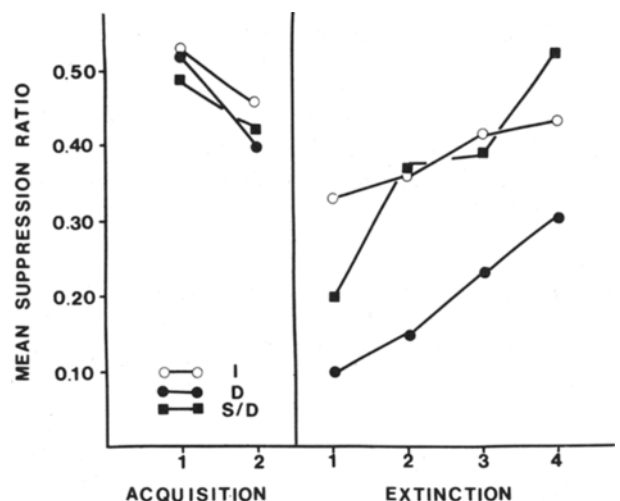
light-conditioning trial and the first noise-extinction test. These two groups are denoted as Group D (delay test) and Group S/D (light-shock/delay test).

Suppression ratios were calculated as  $B/(A + B)$ , where B is the number of responses during the 3-min CS, and A is the number of responses during the 3-min interval immediately preceding the CS (Annau & Kamin, 1961). Rodger's (1975) tables of  $F[E\alpha]$ ,  $v_1$ ,  $v_2$  were used.

### Results and Discussion

Figure 1 presented trial-by-trial mean suppression ratios for the various groups of Experiment 1 during the course of the 2-day conditioning procedure. The left portion of Figure 1 presents suppression ratios obtained during the initial noise-conditioning trials. There were no significant between-groups differences on these trials ( $F_s < 1.0$ ). The right portion of Figure 1 presents suppression ratios obtained during the four nonreinforced presentations of the 3-min noise stimulus. A comparison between Groups I and D, which were treated identically except for the interval of time separating the test of the noise stimulus from the initial noise-shock pairings, indicates that the magnitude of conditioned suppression increased as a function of time since the initial noise-conditioning trials. A comparison between Groups D and S/D indicates that presentation of light-shock pairings immediately prior to the test of the noise stimulus attenuated the time-dependent increase in conditioned suppression observed in Group D.

Trial-by-trial analysis of variance on suppression ratios obtained during the noise-extinction tests indicated significant between-groups differences on all trials ( $F_s$  range from 2.77-6.39). On Extinction Trial 1, Groups I and D were significantly different ( $F = 6.35$ ), and Groups I and D, combined, did not differ from Group S/D ( $F = .04$ ). On Extinction Trials 2-4,



**Figure 1.** Trial-by-trial mean suppression ratios for the groups in Experiment 1. Noise-extinction tests were either immediate (Group I) or delayed (Groups D and S/D) after noise conditioning. Group S/D also received shock prior to the test of noise.

Groups I and S/D did not differ significantly ( $F_s$  of .01, .05, and .61, respectively), and Groups I and S/D, combined, were significantly different from Group D ( $F_s$  of 2.76, 3.07, and 4.43, respectively). Such a set of decisions suggests the following ordering of population mean suppression ratios on these trials: On Trial 1, Group D < Group S/D < Group I; and on Trials 2-4, Group D < Group S/D = Group I.

Baseline rates of responding during the 3-min period immediately preceding the tests of the noise stimulus were not significantly different on Extinction Trials 2-4 ( $F_s < 1.0$ ), but did differ significantly on Extinction Trial 1 ( $F = 4.19$ ). Mean rates of responding during the pre-CS period of Trial 1 were: Group I = 12.00, Group D = 16.30, and Group S/D = 9.42 rsp/min. Thus, baseline differences may have contributed to some of the between-groups differences observed on Noise-Extinction Trial 1.

Thus, Experiment 1 replicated the finding of McMichael (1966) that the magnitude of conditioned suppression elicited by a CS paired with shock increases as a function of time since the initial pairings. It also showed that this increase can be attenuated by presenting light-shock pairings immediately prior to the test of the noise CS. The latter finding suggests the possibility that the incubation phenomenon, or the time-dependent increase in conditioned suppression, may be under control of factors related to US occurrence, rather than under control of changes in the association between the tested CS and the US. The following experiments examined variables that may determine the effects of separate presentations of shock on conditioned suppression.

## EXPERIMENT 2

In Experiment 1, the magnitude of conditioned suppression of responding evoked by a noise stimulus paired with shock was attenuated by presenting two light-shock pairings between the conditioning and test of the noise CS. Experiment 2 evaluated whether a similar attenuation effect can be obtained by presenting shock alone immediately prior to test of the noise CS.

### Method

**Subjects.** Twenty-four male Sprague-Dawley rats served as subjects. There were eight subjects per group. All other conditions were as generally described in Experiment 1.

**Apparatus.** The apparatus consisted of eight identical operant chambers (23.0 × 19.0 × 20.0 cm) enclosed in sound- and light-attenuating shells. Each chamber had a response lever located to the right of a recessed food magazine. The grid floor could be electrified through a relay-sequence scrambler from a high-voltage high-resistance shock source. The two end walls of the chamber were aluminum; the side walls and top were clear Plexiglas. The visual CS was a 24-V white houselight. The auditory CS was a white noise stimulus measuring 80 dB re 20  $\mu$ N/m<sup>2</sup> against a background level of 55 dB.

**Procedure.** The baseline training conditions were as described in Experiment 1. In the conditioning phase, all groups of rats received three presentations of a 3-min noise stimulus that terminated with a .5-sec .8-mA electric shock. All conditioning trials were superimposed on the baseline maintained by the VI 1-min schedule.

The test phase was conducted 24 h after conditioning. Two groups of rats received two presentations of a .5-sec .8-mA electric shock, followed by four nonreinforced presentations of a 3-min noise stimulus. The shocks were signaled by a 3-min light stimulus in Group LS/D (light-shock/delay test), but not signaled by a discrete CS in Group S/D (shock/delay test). Twelve minutes elapsed between either the last light-shock pairing or shock-alone presentation and the first noise-extinction test in these groups. The remaining group of rats also received the same schedule of nonreinforced presentations of the 3-min noise stimulus, but received no light or shock events prior to these tests. This group is denoted as Group D (delay test). The temporal distribution of noise-extinction trials was identical for all groups.

## Results and Discussion

In the initial noise-conditioning phase, there were no significant between-groups differences in suppression ratios on any trial ( $F_s < 1.0$ ).

Figure 2 presents trial-by-trial mean suppression ratios for the groups of Experiment 2 during the course of extinction. Figure 2 shows that Groups S/D and LS/D were less suppressed during the four noise-extinction trials than Group D. Significant between-groups differences in suppression ratios were obtained on Noise-Extinction Trials 1-3 ( $F_s$  range from 3.50-6.71). There were no significant between-groups differences in baseline rates of responding during the 3-min periods immediately preceding any of these trials ( $F_s < 1.0$ ). Post hoc comparisons of suppression ratios revealed that on each noise-extinction trial, Groups S/D

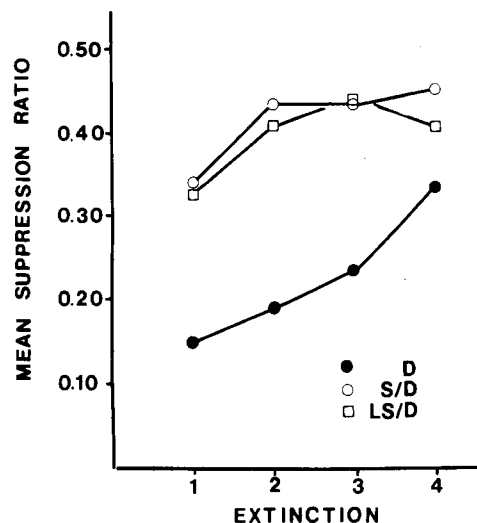


Figure 2. Trial-by-trial mean suppression ratios for the groups in Experiment 2. Noise-extinction tests were delayed after conditioning. Group S/D received shock alone prior to the noise-extinction test, Group LS/D received light-shock pairings prior to the noise-extinction test, and Group D received no shock prior to the noise-extinction test.

and LS/D did not differ significantly ( $F_s$  range from .00-.04), but that Groups S/D and LS/D, combined, differed significantly from Group D ( $F_s$  range from 3.49-6.67). Such a set of decisions suggests the following ordering of population mean suppression ratios on these trials: Group D < Group S/D = Group LS/D.

Experiment 2 replicated the finding of Experiment 1 that postconditioning exposure to light-shock pairings attenuates conditioned suppression evoked by the noise CS. In addition, it showed that this attenuation effect can also be obtained following presentations of shock alone. These outcomes suggest that neither the visual stimulus nor conditioned properties of the visual stimulus contribute to the observed attenuation effect.

### EXPERIMENT 3

The first two experiments have demonstrated that administering either light-shock or shock-alone presentations immediately prior to testing of a CS attenuates responding to that CS. This attenuation effect has been interpreted in terms of the temporal proximity of separate shock presentations to the test of the CS. However, groups evidencing this attenuation effect have differed from control groups both in the proximity of those shock presentations to the test of the CS and in the total number of shocks that they have received prior to the test of the CS. Experiment 3 eliminates the differences in the total number of shocks by evaluating the effects of the temporal proximity between separate shock presentations and the test of the CS.

#### Method

**Subjects and Apparatus.** Twenty-four male Sprague-Dawley rats served as subjects. There were eight subjects per group. All other conditions were described in Experiment 1. The apparatus was as described in Experiment 1.

**Procedure.** The baseline training procedure was described in Experiment 1. In the first conditioning session, all groups of rats received two presentations of a 3-min noise stimulus that terminated with a .5-sec .5-mA electric shock, as described in Experiment 1. Group S/I (shock immediate) also received two additional presentations of a 3-min light stimulus that terminated with a .5-sec .5-mA electric shock in the same session. The remaining two groups of rats, Group S/D (shock delay) and Group D (delay), responded on the VI 1-min schedule at this time.

In the second conditioning session, all groups received four non-reinforced presentations of the 3-min noise stimulus. However, Group S/D received two presentations of a 3-min light stimulus that terminated with a .5-sec .5-mA electric shock prior to the first noise-extinction test. The second light-shock pairing occurred 9 min prior to the first noise-extinction trial.

#### Results and Discussion

There were no significant differences in suppression ratios between these groups during the initial two noise-conditioning trials, or between Groups S/I and S/D during their two light-conditioning trials ( $F_s < 1.0$ ).

Figure 3 presents trial-by-trial mean suppression ratios for the various groups during the course of extinction testing. This figure shows that both Groups

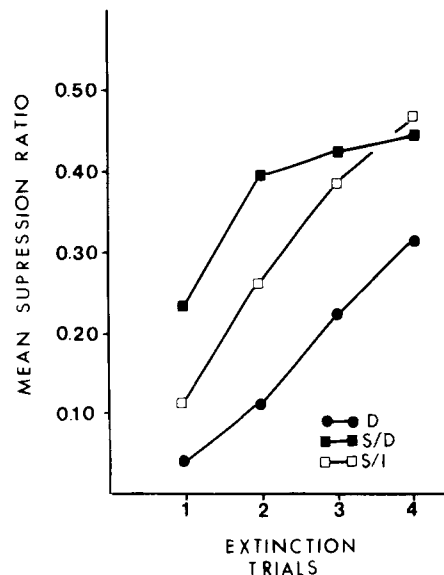


Figure 3. Trial-by-trial mean suppression ratios for the groups in Experiment 3. Noise-extinction tests were delayed after initial noise conditioning. Group S/I received additional shock immediately after conditioning, Group S/D received additional shock just prior to the test of noise, and Group D received no additional shock.

S/I and S/D evidenced less conditioned suppression of responding than did Group D during the noise-extinction tests. The magnitude of this attenuation effect was greater in Group S/D than in Group S/I on Extinction Trials 1 and 2, but thereafter the groups converged.

Analysis of variance on suppression ratios obtained during the extinction procedure indicated significant between-groups differences on Extinction Trials 1-3 ( $F_s$  range from 2.82-7.78). Post hoc comparisons revealed that on Extinction Trials 1 and 2, Groups D and S/D were significantly different ( $F_s$  of 3.28 and 7.77), but that Groups D and S/D, combined, did not differ significantly from Group S/I ( $F_s$  of .10 and .01). On Extinction Trial 3, Groups S/D and S/I did not differ significantly ( $F = .10$ ), but these two groups, combined, differed significantly from Group D ( $F = 2.77$ ). This set of decisions suggests the following orderings of population mean suppression ratios: On Extinction Trials 1 and 2, Group D < Group S/I < Group S/D; and on Extinction Trial 3, Group D < Group S/I = Group S/D.

Baseline rates of responding were significantly different between groups during the period immediately preceding the first extinction trial ( $F = 3.48$ ), but did not differ during the periods preceding the second and third extinction trials.

This difference confirms the view that the temporal proximity of shock to the test of the CS is an important factor for attenuating conditioned suppression of responding, but does not rule out the possibility that the attenuation effect results from greater habituation following additional shock presentation.

## EXPERIMENT 4

In all of the preceding experiments, the intensity of separate shock presentations was the same as that used during the conditioning of the noise CS. Experiment 4 evaluates how the intensity of separate shock presentations influences the magnitude of the attenuation effect.

## Method

**Subjects and Apparatus.** Thirty-two male Sprague-Dawley rats served as subjects. There were eight subjects per group. All other conditions, as well as the apparatus used, were as described in Experiment 1.

**Procedure.** The baseline training procedure was as described in Experiment 1. In the first conditioning session, all groups received two presentations of a 3-min noise stimulus that terminated with a .5-sec .5-mA electric shock, as described in Experiment 1. The conditioning trials were superimposed on the VI 1-min baseline.

In the second conditioning session, three groups of rats received two presentations of a 3-min light stimulus that terminated with a .23-, .50-, or 1.0-mA electric shock. The remaining group of rats received no light-shock pairings. The various groups are denoted as .23, .5, 1.0, and D (delay). All groups then received four nonreinforced presentations of the 3-min noise stimulus. The first noise test trial occurred 12 min after the second light-shock presentation. Four additional nonreinforced presentations of the 3-min noise stimulus were presented 24 h later in a second extinction-conditioning session.

## Results and Discussion

There were no significant between-groups differences in suppression ratios obtained during the initial two noise-conditioning trials ( $F_s < 1.0$ ). Figure 4 presents trial-by-trial mean suppression ratios for the various groups of Experiment 4 over the course of the two extinction sessions. This figure

indicates that on the initial noise test trial, all groups receiving light-shock presentations were less suppressed than Group D. The magnitude of the attenuation effect was inversely related to the intensity of those shocks, and, in general, this pattern was maintained during the subsequent extinction trials, with the exception of Group 1.0. This group showed little loss of conditioned suppression during Noise-Extinction Trials 1-4, and showed greater conditioned suppression than Group D during Noise-Extinction Trials 5-8.

Although trial-by-trial analyses of variance on suppression ratios indicated significant between-groups differences during all extinction trials ( $F_s$  range from 2.26-6.69), only Trials 1 and 5 were analyzed with post hoc comparisons. On Trial 1, Group D differed from Group .5 ( $F = 2.74$ ); Group .23 differed from Group 1.0 ( $F = 2.44$ ); and Groups D and .5, combined, did not differ from Groups .23 and 1.0 combined ( $F = .95$ ). This suggests the following order of mean population suppression ratios on Trial 1: Group D < Group 1.0 < Group .5 < Group .23. On Trial 5, Group D did not differ from Group .5 ( $F = .12$ ); Groups D and .5, combined, did not differ from Group 1.0 ( $F = .57$ ); and Groups D, .5, and 1.0, combined, differed significantly from Group .23 ( $F = 3.31$ ). This suggests the following ordering of mean population suppression ratios on Extinction Trial 5: Group 1.0 = Group D = Group .5 < Group .23. These analyses confirm the view that postconditioning exposure to .23-mA shock results in greater attenuation of conditioned suppression than does similar exposure to .5-mA shock. Although additional analyses indicated that Group 1.0 showed significantly greater conditioned suppression than Group D on Extinction Trials 6-8, the suppres-

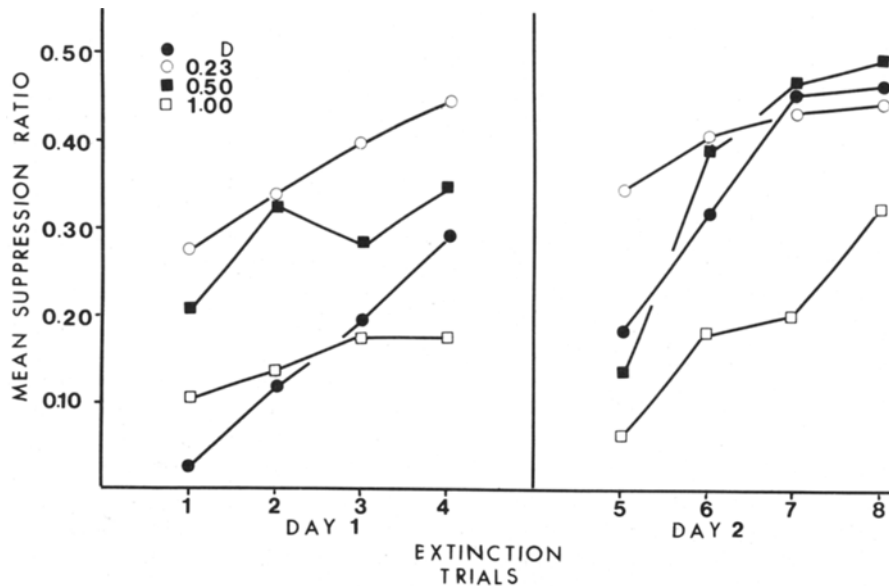


Figure 4. Trial-by-trial mean suppression ratios for the groups in Experiment 4. Groups .23, .50, and 1.00 received shock just prior to noise-extinction tests, whereas Group D did not.

sion ratios obtained from Group 1.0 may be confounded by low baseline rates of responding. Significant between-groups differences in rates of responding were obtained on every extinction trial except Trial 2 ( $F_s$  range from 2.85-6.14). However, in every instance, these differences were attributable to low baseline rates in Group 1.0. Mean rates of responding during the pre-CS period averaged across all extinction test trials were: Group D = 14.50; Group .23 = 18.46; Group .5 = 15.36; and Group 1.0 = 8.78.

Thus, Experiment 4 showed that the magnitude of the attenuation effect is inversely related to the intensity of postconditioning shock. This pattern of results seems inconsistent with many of the potential accounts mentioned previously and will be discussed in the General Discussion section.

### GENERAL DISCUSSION

The outcomes of the present experiments are consistent with those of previous studies showing that performance of a first-order CR to a previously conditioned stimulus can be modified by separate presentations of the US (Colby & Smith, 1978; Rescorla, 1973, 1974; Sherman, 1978). On the basis of these outcomes, some preliminary suggestions can be made about the variables that determine the effects of separate presentations of the US and possible mechanisms of conditioning that may govern the operation of those variables.

Previous studies have reported that repeatedly presenting the organism with a US of the same intensity or concentration as the original conditioning US attenuates the magnitude of the first-order CR to a previously conditioned stimulus (Colby & Smith, 1978; Rescorla, 1973). However, these attenuation effects were small and required repeated extinction tests for detection. Moreover, a notable number of studies have failed to obtain any significant attenuation in the magnitude of the first-order CR with this treatment (Ayres & Benedict, 1973; Brookshire & Brackbill, 1976; Holman, 1976; Rescorla, 1974; Riley, Jacobs, & LoLordo, 1976; Sherman, 1978). These studies were all characterized by the use of a long delay interval between separate presentations of the US and the test of the target CS. In the present experiments, an inverse relationship was observed between the magnitude of the attenuation effect and the delay interval between separate presentations of the US and the test of the target CS. This finding suggests that the choice of a long delay interval until the test of the target CS in previous studies may have impeded the detection of an attenuation effect resulting from separate presentation of the US. It should also be noted that a similar inverse relationship has been demonstrated in studies assessing the effects of separate presentation of the US on acquisition of a

first-order CR (Best & Domjan, 1979; Domjan & Best, 1977).

In contrast, several studies have reported that repeatedly presenting the organism with a US of greater intensity than the original conditioning US increases or "inflates" the magnitude of the first-order CR to a previously conditioned stimulus (Rescorla, 1974; Sherman, 1978). These studies were also characterized by a long delay interval between separate presentations of the US and the test of the target CS. A similar inflation effect was obtained in Experiment 4 of the present studies, but only during the second session of extinction testing, that is, 24 h after separate shock presentation. This finding suggests that the choice of a long delay interval until the test of the target CS may facilitate detection of an inflation effect.

One possible explanation of these effects is based upon the view that separate presentations of shock result in conditioning of situational cues. In the present circumstances, the CR evoked by conditioned situational cues may elevate the background level of the response, thereby diminishing the capacity of the target CS to evoke a strong CR, that is, the law of initial values (Wilder, 1956). Although this view is contrary to the expectation that the response-evoking properties of situational cues would summate with those of the first-order CS to augment the magnitude of the CR (Bouton & Bolles, 1979; Hull, 1943; Rescorla & Wagner, 1972), it is consistent with the finding of disruption of baseline rates of responding immediately following separate presentations of shock in several of these experiments (Dweck & Wagner, 1970). Moreover, the inverse relationship between the magnitude of the attenuation effect and the delay interval separating exposure to shock and the test of the target CS could be attributed to differential amounts of nonreinforced exposure to situational cues. Animals with a long delay until test would have a greater opportunity for extinction of conditioning of situational cues relative to animals with a short delay to test and, hence, a greater loss of interference by conditioned situational cues. However, there is evidence to suggest that conditioned situational cues are not primarily responsible for these effects. First, the magnitude of the attenuation effect was inversely related to the intensity of separate shock presentation. One would expect the opposite relationship if conditioning of situational cues is directly related to the intensity of shock, a relationship true for discrete CSs (Annau & Kamin, 1961). Second, the presence of a discrete signal of separate shock presentations did not reduce the magnitude of the attenuation effect relative to the un signaled treatment. The presence of a discrete signal should minimize conditioning of situational cues via overshadowing (Pavlov, 1927) and, hence, reduce the magnitude of the attenuation effect relative to the un signaled treatment. It should be noted, however, that any such overshadowing ef-

fect would be small, given only two separate presentations of shock. These arguments are not meant to imply that conditioning of situational cues plays no role in mediating these effects of separate shock presentations, but rather, that any role served by conditioned situational cues is not readily apparent in the present studies.

A second potential account of these effects can be derived from the opponent-process theory of acquired motivation (Solomon & Corbit, 1974). This theory would assert that an initial excitatory response resulting from separate presentation of shock is followed by an inhibitory aftereffect that is capable of attenuating the response to subsequently presented excitatory stimuli, for example, the noise CS. Although the basic finding of attenuation of the first-order CR following separate presentations of shock is consistent with this view, the inverse relationship between the magnitude of the attenuation effect and the intensity of separate shock presentations is not. The opponent-process model clearly predicts that the magnitude of the attenuation effect should be directly related to the intensity of those separate shock presentations because the strength of the inhibitory aftereffect is postulated to increase with US intensity.

The information-processing model of Wagner (1976, 1979, 1980) has provided a reasonable account of findings obtained in previous studies of separate presentations of the US. In the present circumstances, however, this model predicts that separate presentations of shock should either have no effect or augment the first-order CR. This should occur because priming short-term memory (STM) with a representation of the shock US would be expected to lower the threshold required for the CS to evoke a CR, as long as the unconditioned response to shock mimics the CR (Wagner, Note 1). Clearly, the outcomes of these experiments are counter to the predictions of this model.

A final explanation of these findings can be derived from the framework provided by an event-memory model of conditioning (Konorski, 1967; Rescorla, 1974; Sokolov, 1963). This model asserts that the status of the US representation is modified following each exposure to the US, and that such modifications will be reflected in the CR evoked by any CS representation having an association with the US representation. On the basis of the present findings, some preliminary suggestions can be made about the role of temporal and US intensity variables in modifying the status of the US representation.

First, the present observations suggest that important changes in the status of the US representation occur with the passage of time. Specifically, an initial exposure to the US, either alone or in the context of CS-US pairings, is assumed to result in the formation of a US representation. The US representation is then postulated to undergo an autonomous increase in strength with the passage of time. It is

this autonomous increase in the strength of the US representation with time that is considered to be at least partially responsible for the "incubation" phenomenon, that is, the progressive increase in the magnitude of conditioned suppression as a function of time since CS-US pairings (McMichael, 1966; Experiment 1).

A second suggestion is that each reactivation of the US representation, as may be occasioned by separate presentations of the US, initiates a comparison between the presented US and the US representation that it arouses (Sokolov, 1963). If there is a discrepancy between the US representation and the actual US, then the US representation is modified to conform to the actual US. This comparison process serves to bring the US representation into line with the actual US, thereby promoting a more accurate US representation.

The present findings may then be accommodated by assuming that it is the autonomous growth of the US representation following initial CS-US pairings that creates a discrepancy between the separately presented USs and the US representations that they arouse. In this sense, the autonomous growth process can be viewed as resulting in a US representation that exceeds the value of the actual US. Reactivation of the US representation through separate presentations of the US serves to reduce the excessive US representation and bring it into line with the actual US. Thus, separate presentations of shock would be expected to attenuate the magnitude of conditioned suppression of responding relative to control animals by reducing the US representation autonomously inflated by the passage of time. This view predicts that presenting the organism with shocks of weaker intensity than the original conditioning shock should markedly reduce the inflated representation of shock and, hence, the CR to any associated CS. Presenting the organism with shocks substantially more intense than the original conditioning shock, that is, shocks that exceed the representation of the conditioning shock increased through the passage of time, should augment the US representation and, hence, the CR to any associated CS (Rescorla, 1974; Experiment 4).

Finally, any US representation formed as a consequence of this comparison process will again undergo an autonomous increase in strength with the passage of time. This would account for the findings of Experiment 3, in which light-shock presentation occurring in close temporal proximity to the test of the noise stimulus resulted in a larger attenuation effect than light-shock presentations temporally displaced from the test of the noise CS. It would also account for the finding of Experiment 4, in which separate presentations of a 1.0-mA shock appeared to retard extinction of the noise stimulus and increase the CR during the second extinction session. In the present view, the representation of the 1.0-mA electric shock formed as a consequence of the comparison

process progressively increased in strength with the passage of time, thereby counteracting the effect of the extinction treatment. This raises the question of the variable that controls the magnitude of the postulated autonomous growth process. One possibility is the degree of discrepancy between the actual US and the US representation that it arouses. This predicts that the largest autonomous growth process should occur following the initial CS-US pairings of a conditioning procedure, because the value of the US representation can be said to be of "zero" strength at this time. Moreover, this view would predict that there should be autonomous growth of the US representation in any conditioning situation in which a US intensity shift is implemented, regardless of the relative intensity change involved in that shift. This might account for the recent finding of Randich and LoLordo (1979b) that the magnitude of the attenuation of conditioned suppression of responding resulting from repeated prior exposure to shock is an inverted U-shaped function of shock intensity during the preexposure phase.

This modified event-memory model may also be used to accommodate what appears to be a contradictory effect of postextinction presentation of the US. Under such conditions, the CR to the CS is augmented rather than attenuated by exposure to the US and is referred to as the reinstatement phenomenon (Bouton & Bolles, 1979; Pavlov, 1927; Rescorla & Heth, 1975). Although Bouton and Bolles (1979) have demonstrated that the conditioning of situational cues is sufficient to produce reinstatement, the framework of the event-memory model provides a reasonable alternative. Rescorla and Cunningham (1978) asserted that, during an extinction procedure, the CS-aroused US representation or CR occurs in the absence of any following US. Any comparison process intended to reduce the discrepancy between the CS-aroused US representation and the actual US (i.e., one of "zero" strength) would reduce the strength of the US representation. As a consequence, part of the decrement in the CR to the CS in an extinction procedure may result from a reduced US representation. Thus, postextinction exposure to the US alone would strengthen the US representation by initiating a comparison process and partially restore the CR to the CS (Rescorla & Heth, 1975). Moreover, Rescorla and Cunningham (1978) have recently identified an autonomous increase in the strength of the US representation following extinction, which is analogous to that observed in the present experiments during acquisition. They identified this change in the US representation as partially responsible for spontaneous recovery. Thus, between-sessions incubation of the CR to a CS undergoing initial conditioning, loss of the attenuating effect of separate presentations of the US with the passage of time, and spontaneous recovery of the CR to an extinguished CS may all reflect an autonomous time-

dependent growth of the US representation formed as a consequence of a comparison process. Consequently, the assumptions that the US representation autonomously increases with time since US exposure and is governed by a process that reduces the discrepancy between the actual US and the current representation of the US are consistent with data from a variety of conditioning settings.

#### REFERENCE NOTE

1. Wagner, A. R. *SOP: A model of automatic memory processing in animal behavior*. Paper presented at the Binghamton Symposium on Memory Mechanisms in Animal Behavior, SUNY at Binghamton, June 10-12, 1980.

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