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Concurrent observations of barpress suppression and freezing: Effects of CS modality and on-line vs. off-line training upon posttrial behavior

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In a conditioned suppression study with rats, CS modality (light vs. noise) and type of conditioning (on-line vs. off-line training) were manipulated. All rats were then tested on-line with only half the test trials reinforced. Some results and conclusions were as follows: (1) During initial training, suppression following reinforced noise trials was moderately strong at first but weakened over days; for the light, it was weak from the start. It was suggested that this strong influence of CS modality might complicate interpretations of posttrial suppression as a measure of US effectiveness. (2) During testing, posttrial suppression and freezing were greater following nonreinforced trials than following reinforced trials (US-omission effect), and this effect was stronger for noise than for light. Since noise also produced more freezing than light, this result favors the hypothesis that the US-omission effect is due to persistent CS-elicited freezing that is undisrupted by a shock US. (3) Although noise produced more freezing, both noise and light produced similar barpress suppression. This result is consistent with the suggestion that noise and light acquire equal associative strength but elicit different defensive behaviors.

In a recent study of conditioned suppression of barpressing in the rat, Ayres and Vigorito (1984) examined their subjects' behavior in a 1-min period following each trial. They found that when a white-noise conditioned stimulus (CS) coterminated with a single brief electric-grid-shock unconditioned stimulus (US), the rats' barpressing in this 1-min posttrial period was at first moderately suppressed. With further training, however, this suppression gradually decreased. If a second shock US was then added 1 min after the first, suppression in this same 1-min posttrial period (now the period between the two shocks) gradually increased until it approached its original level. If shocks were omitted on some trials but presented on others, posttrial suppression was greater following shock omission than following shock presentation (US-omission effect). Finally, direct observations of the rats' behavior disclosed that the rats froze more following shock omission than following shock presentation. To account for these results, Ayres and Vigorito proposed that two factors were important:

First, in the usual conditioned suppression procedure in which trials are widely spaced, the temporal stimuli that closely follow a shock presentation are explicitly unpaired with the following shock, and therefore gradually acquire the ability to inhibit fear conditioned to contextual cues or fear possibly initiated by the CS and persisting beyond it (Ayres, Mahoney, Proulx, & Benedict, 1976; Davis, 1970; Davis & McIntire, 1969; Davis, Memmott, & Hurwitz, 1975; Reberg & Memmott, 1979). This conditioned inhibition factor could account for the gradual loss of posttrial suppression seen with training. Of course, if the posttrial temporal stimuli themselves were made to precede shock, then they should lose their inhibitory properties and become excitatory, and posttrial suppression should increase. This is a result that Ayres and Vigorito found.

Second, barpress suppression and freezing are greater following shock omission than following shock presentation because freezing initiated by the CS persists beyond CS termination unless disrupted by shock (Bolles & Riley, 1973; Fanselow, 1982). The disruption of freezing by shock permits barpressing to be resumed. In support of this "freezing hypothesis," Ayres and Vigorito noted that there was a positive correlation between posttrial freezing and the amount of freezing during the CS, and that both of these measures were correlated with posttrial barpress suppression. Ayres and Vigorito also mentioned their unpublished observation that there was more posttrial suppression following shock omission after a noise CS than after a light CS. This observation was also consistent with the freezing account of the US-omission effect, because more freezing was also observed during the

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noise than during the light. The more a CS tends to evoke freezing, the more freezing should tend to persist into the posttrial interval unless disrupted by shock. Hence, the greater the freezing during a CS, the greater should be the US omission effect.

The present study had two aims. One was to attempt to document the previously unpublished observations just described concerning differences in both CS-elicited and posttrial freezing produced by noise and light and, in so doing, to assess the freezing account of the US-omission effect. A second was to test an alternative to the conditioned inhibition account of the decline of posttrial suppression that occurs when each CS is followed by a single shock. The alternative account tested was based on the following consideration. In the conditioned suppression procedure, barpressing is usually reinforced on a VI schedule. When suppression occurs during a CS, chances are high that a reinforcer will be "set up" but not earned by a barpress. The first response to follow a shock will therefore usually produce the reinforcer that was set up before the shock delivery. Thus posttrial suppression may decline, not because the rat learns that the postshock period is safe, but rather because the rat gradually learns that a shock sets the occasion upon which a response, if emitted, will be reinforced (Davis, 1970, Footnote 1).[1] To test this "shock-as-an-S^D hypothesis," we gave half the rats in the present study CS-US pairings "off-line," that is, while they were prevented from barpressing and eating. For those rats, the shock could not become a discriminative stimulus for barpressing. The remaining rats received CS-US pairings in the usual "on-line" manner so that the shock could potentially become a discriminative stimulus for barpressing. Of interest was the posttrial suppression in the two groups when tested on-line following this training. If inhibition conditioned to posttrial temporal stimuli accounts for the loss of posttrial suppression, then both groups should show little posttrial suppression on test. But if learning about shock as an S^D is crucial, only the rats trained on-line should show weak posttrial suppression on test. Finally, half of each of these groups were trained with a noise CS and half with a light CS; this was done in order to document the earlier unpublished observations of Ayres and Vigorito concerning the relationship between CS- and posttrial-freezing and suppression and, in so doing, to assess the freezing account of the US-omission effect.

METHOD

Subjects

The subjects were 32 experimentally naive male albino rats, 90 days old on arrival from the Holtzman Company, Madison, Wisconsin. They were housed individually in suspended wire-mesh cages in a continuously lighted colony. For 1 week, they were adapted to the colony; over the course of a 2nd week, they were reduced to 80% of their free-feeding body weights, and were maintained at that weight for the duration of the experiment.

Apparatus

Eight Gerbrands Skinner boxes were housed in ventilated .61-m cubes of 12.7-mm plywood lined with acoustical tile. Any three of the wooden front doors of these cubes could be replaced by three portable doors constructed of two sheets of Plexiglas separated by a 6.5-cm-thick wooden frame. These portable Plexiglas doors permitted up to three rats to be directly observed simultaneously under relatively sound-proofed conditions. Mounted on the inside rear wall of each cube was a 7.5-W 110-V red light bulb; it was illuminated throughout the study to permit direct observation of the rats' freezing behavior. Mounted outside and above the cubes, and out of the rats' line of sight, was a small relay rack containing a relay, a Lehigh Valley Model 1356 indicator lamp panel, and two other 28-V red lamps; these devices all provided pacing stimuli (see procedure) designed to pace direct observations of freezing.

The inside dimensions of each Skinner box were 23.2 × 20.3 × 19.5 cm. Each floor was composed of 18 stainless steel rods, 2 mm in diameter, mounted 1.3 cm apart center to center. The end walls were aluminum; the sides and top were transparent Plexiglas. Centered in one end wall was a standard Gerbrands bar, 1.5 × 5.0 cm, mounted 8 cm above the grid floor. In the lower left corner of this same wall was a 5.5 × 5.0 × 5.0 cm recessed dipper receptacle.

On the lid of each Skinner box were two 10-cm speakers. One provided an intermittent (1 sec on, .11 sec off) white-noise CS of approximately 80-dB intensity re 20 $\mu N/m^2$; the other was not used. A second CS was provided by the synchronous flashing (1 sec on, .11 sec off) of two 28-V bulbs, one a cue light mounted over the dipper opening 95 mm above the grid floor, the other a bulb mounted on the chamber lid. Scrambled grid shocks (1 mA for 1 sec) served as USs and were provided by eight Grason-Stadler shock sources (Models E1064GS and 700). Barpressing, the response to be suppressed by CS trials, was reinforced with 4-sec presentations of a .1-ml dipper cup containing a 32% (by weight) sucrose solution. Solid state programming apparatus and a paper-tape reader were used to program both the Pavlovian and operant contingencies, and a computer was used to record data and to provide a pulse stream to pulse the stimuli that paced the direct observations.

Procedure

Preliminary training. Preliminary training, designed to establish barpress behavior to be suppressed later by CS trials, began at the start of the 3rd week after the rats' arrival at the laboratory. It began with a .5-h session of magazine training, during which the dippers were presented for 3 sec at variable times. In addition, each barpress also produced a 4-sec presentation of the dipper. On the next 3 days, the rats were shaped to barpress, and each response produced a 4-sec dipper presentation. On the last 2 of these 3 days, each rat was removed from the box as soon as it earned 90 reinforcers. On each of the next 5 days, a VI 1-min schedule of reinforcement was in effect. These five sessions and all the remaining sessions in the experiment were 1 h long.

Pavlovian conditioning. Pavlovian conditioning involved four daily presentations of a 2-min CS that coterminated with a 1-sec 1-mA scrambled grid shock US. For half the rats, the CS was a white noise (N) of 80 dB (re: 20 $\mu N/m^2$). For the remaining rats, the CS was a light (L) produced by turning on the cue light on the work panel plus the 28-V bulb mounted on the lid of the Skinner box. For both groups, the CS was intermittent (1 sec on, .11 sec off). For half of each group, the CS-US pairings occurred "on line," that is, while the rats barpressed for sucrose on the VI schedule. For the remaining rats of each group, the CS-US pairings occurred "off line," that is, while the rats were separated from the bar and from the dipper by a Plexiglas panel placed in front of the work panel. Intervals between successive CS onsets were variable and ranged from 7 to 16 min. Pavlovian conditioning lasted for nine 1-h daily sessions (36 trials).

Operant recovery. Following the Pavlovian conditioning phase were two daily 1-h sessions in which all rats were allowed to barpress on the VI schedule in the absence of CSs and USs; the aim was to ensure that in the next phase the rats previously trained offline would respond at rates comparable to those of rats previously trained on-line.

Test. Following operant recovery were three daily 1-h sessions designed to assess CS-elicited supression and posttrial suppression of barpressing in all rats. Only half of the CS trials were reinforced so that the posttrial effects of shock presentation vs. shock omission could be compared. Trials 1 and 3, 2 and 4, and 1 and 4 were reinforced on Test Days 1, 2, and 3, respectively.

Direct observations. The Plexiglas doors were used in Boxes 1, 2, and 3 on the 1st day of Pavlovian training, in Boxes 4, 5, and 6 on the 2nd day, and in Boxes 7 and 8 on the 3rd day. This rotation was repeated on Days 7, 8, and 9 and again on Test Days 1, 2, and 3. The rats were directly observed by two experimenters on the days that their boxes were fitted with the Plexiglas doors. Each rat thus provided an "initial" measure of freezing during Pavlovian training (Day 1, 2, or 3), a "terminal" measure (Day 7, 8, or 9), and a "test" measure (Test Day 1, 2, or 3). A time sampling procedure was used to score freezing (cf. Bouton & Bolles, 1980; Fanselow & Bolles, 1979; Sigmundi, Bouton, & Bolles, 1980). For 5 sec prior to the start of each pre-CS, CS, and posttrial interval, six of the indicator lamps above the housing chambers lit up as a ready signal to the experimenters. At the termination of this signal, the experimenters scored the behavior of the first rat and then, paced by the relay clicks produced by the pulse stream (.5 sec on, 1.5 sec off) from the computer, shifted their gaze to Rat 2 and then Rat 3 of each set of rats to be observed, scoring the behavior of each in turn. The two red "pacing" lamps above the housing chambers cycled on and off in such a way that every third termination was a signal for scoring the behavior of Rat 1. In this way, both experimenters examined the same rat at the same time, 10 times per minute for each rat. The relay clicks and flashing pacing lamps were always present throughout the session so that even if somehow detected by the rats, their presence in a pre-CS interval could not be a signal for CS presentations.

Each observation was scored as either "freezing" or "not freezing." Freezing was defined as the absence of any movement except for the movement of the rat's sides required for breathing. "Not freezing" was defined as anything else.

Treatment of Data

Barpress suppression was indexed in terms of the Annau and Kamin (1961) suppression ratio, $D/(B + D)$; here D refers to the number of responses during a 2-min CS, and B refers to the number in the 2-min period before the CS. A similar ratio, $2A/(B + 2A)$, was used to measure suppression in the 1-min period after each CS; here A refers to the number of responses occurring in that 1-min period. Following Ayres and Vigorito (1984), a "corrected ratio" was also computed. This ratio was similar to the ones already described, except that the B score for each rat on each trial of the Pavlovian conditioning phase was the B score from Trial 1 of the 1st day of Pavlovian conditioning; during the test phase, the B score was taken from the first trial of the 1st test day. The purpose of using the corrected ratios was to ensure that any systematic changes in suppression ratios across days were due to changes in D or A scores and not to changes in B scores (cf. Ayres, Berger-Gross, Kohler, Mahoney, Stone, 1979). The results with this measure, however, proved virtually identical to those with the Annau-Kamin ratio and supported the same statistical conclusions; therefore, only the more conventional Annau-Kamin ratio will be described below. With this ratio, a score of 0 denotes strong suppression and a score of .5 suggests no effect.

Freezing was measured in terms of the percentage of the observations in the B, D, and A periods that received a freezing score. Since two observers scored each trial, the mean of their percent freezing scores for each trial was used in statistical analyses and for graphical presentation. Agreement between observers was such that of the 36 data points to be presented, only two differed by as much as 3% from the corresponding point determined by each observer.

Results were analyzed using a priori two-tailed nonparametric statistical tests described by Hollander and Wolfe (1973).

RESULTS

Figure 1 shows the course of barpress suppression across the 9 days of the Pavlovian training phase. The lower curves show the suppression during the CS, and the upper curves show the suppression in the first posttrial minute. Suppression during the CS was very similar for the groups trained with light and noise; when the results were averaged across all 9 days (36 trials), a Wilcoxon rank sums test for independent groups showed no significant difference between groups [$T(8,8) = 64$, $p > .50$].

Posttrial suppression (upper curves) tended to weaken across days for the noise group, as previously described by Ayres and Vigorito (1984); suppression on the last day was significantly weaker than suppression on the first [Wilcoxon signed ranks test for matched pairs, $T(8) = 0$, $p = .01$]. However, this was not so for the light CS [$T(8) = 13$, $p > .40$]; there was little posttrial suppression in the light group on any day of the Pavlovian training phase.

The left-hand part of Table 1 shows the group mean pre-CS rates on each day of the Pavlovian training phase. When the data were averaged across the 9 days, the groups did not differ on this measure [$T(8,8) = 73$, $p > .50$].

The left panel of Figure 2 shows the freezing that occurred at the end of Pavlovian training (terminal freez-

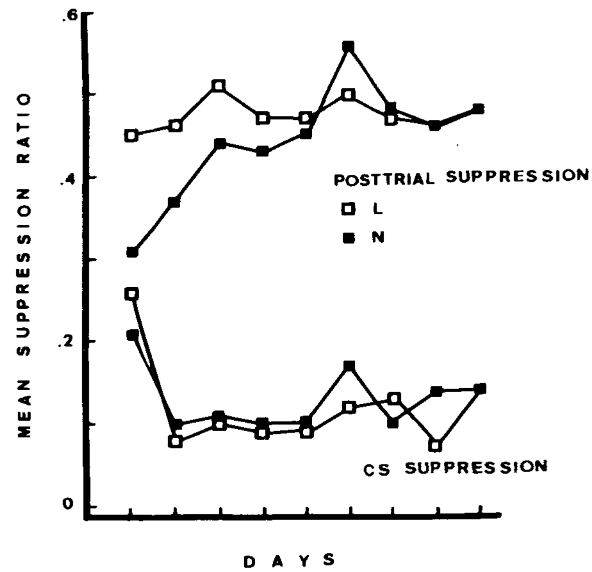

Figure 1. Course of CS-elicited barpress suppression (lower curves) and posttrial suppression (upper curves) across the 9 days of Pavlovian training.

Table 1
Mean Number of Responses per 2-Minute Pre-CS Period

	Pavlovian Training Days									Test Trials											
Group	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	10	11	12
ON/N	35	30	24	33	26	20	31	34	30	40	30	33	32	41	34	32	32	41	38	38	36
OFF/N										40	24	23	25	36	31	33	30	34	29	25	33
ON/L	35	37	30	33	34	35	35	38	38	50	41	41	45	47	44	40	52	51	41	39	39
OFF/L										44	39	37	42	44	39	35	36	38	33	33	34

Note—Scores were averaged over the four trials of each session during Pavlovian training. Abbreviations: ON/L = trained on line with light CS; OFF/N = trained off line with noise CS, etc.

ing measure). The panel shows that rats trained off-line froze more in every period (B, D, and A) than did the rats trained on-line [Ts(16) > 360, ps < .01] and that during the CS the rats trained with noise froze more than those trained with light [T(16) = 206.5, p < .05]. Freezing that occurred earlier in Pavlovian training (the initial freezing measure) is not shown in Figure 2, but it was very similar to the freezing that is shown. Of potential relevance to the hypothesis that posttrial temporal stimuli become inhibitory with training is the observation that there was no decline in posttrial freezing from the initial freezing measure to the terminal freezing measure (means for all 32 rats = 7.9% and 8.5%, respectively). However, there was so little posttrial freezing at the start of training that it might be unreasonable to expect posttrial freezing to show any further decline.

During the 3 days of testing that followed Pavlovian training and recovery, the CS elicited strong suppression of barpressing in all four groups. When the results were averaged across all 12 test trials, the mean suppression ratios for rats trained on-line with noise, off-line with noise, on-line with light, and off-line with light, respectively were .14, .08, .17, and .05. Suppression was significantly greater for rats trained off line (mean = .06) than for rats trained on line (mean = .15) [T(16,16) = 188, p < .01]. There was no difference between rats trained with noise (mean = .11) vs. light (mean = .11).

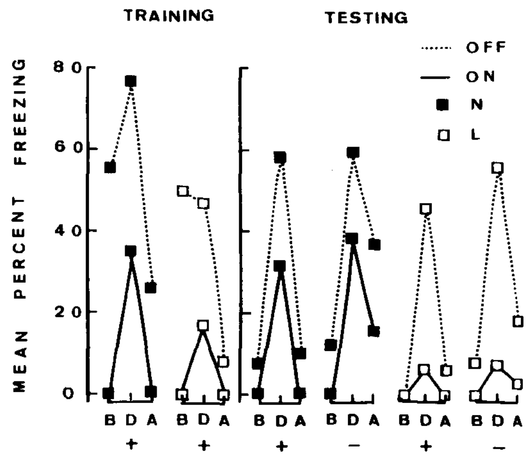

Figure 2. Left panel: Percent freezing before, during, and after the CS during Pavlovian training as reflected in the "terminal freezing measure." Right panel: Percent freezing during testing. Reinforced trials are denoted by "+," and nonreinforced trials are denoted by "−."

Figure 3 shows the posttrial barpress suppression across the 12 trials of testing. Data from the two noise groups are shown to the left, and data from the two light groups are shown to the right. The first trial was reinforced and was intended as a test of the "shock-as-S^D hypothesis." If posttrial suppression weakens with training because the shock adventitiously comes to serve as an S^D, then rats given Pavlovian training off-line should show more posttrial suppression on this trial than should rats trained on-line. Figure 3 shows exactly this outcome [T(16,16) = 175, p < .01].

The second test trial was nonreinforced and was included in an attempt to replicate the US-omission effect observed by Ayres and Vigorito (1984). Thus, more posttrial suppression was expected following shock omission on this trial than following shock presentation on the preceding trial for rats trained with noise; and, based on unpublished results mentioned by Ayres and Vigorito, this effect was expected to be smaller in magnitude for the rats trained on-line with light than for rats trained on-line with noise. Figure 3 supports these expectations: Posttrial suppression was greater following shock omission than following shock presentation in both the noise rats [T(14) = 3, p < .01] and the light rats [T(15) = 17, p < .05]; and an analysis of drop scores (Trial 1 ratios minus Trial 2 ratios) showed that the effect was more pronounced in the rats trained on-line with noise than in the rats trained on-line with light [T(8,8) = 45.5, p < .05].

The results of the remaining test trials appeared to support the statements just made about the first two trials. Thus, the rats trained off-line continued to suppress more than those trained on-line; and, with the exception of Test Day 2 for the group trained on-line with light, the US-omission effect persisted throughout testing.

Pre-CS rates during the test sessions are shown in the right-hand part of Table 1. Statistical analyses were performed on the data of the first two trials, since suppression ratios were analyzed statistically on these trials. Kruskal-Wallis analyses of variance found no significant differences among groups (Hs < 3.34). Thus, differences described above in terms of suppression ratios were not confounded by differences in pre-CS rates.

The right-hand panel of Figure 2 shows the freezing that occurred during testing. The figure shows a variety of effects.

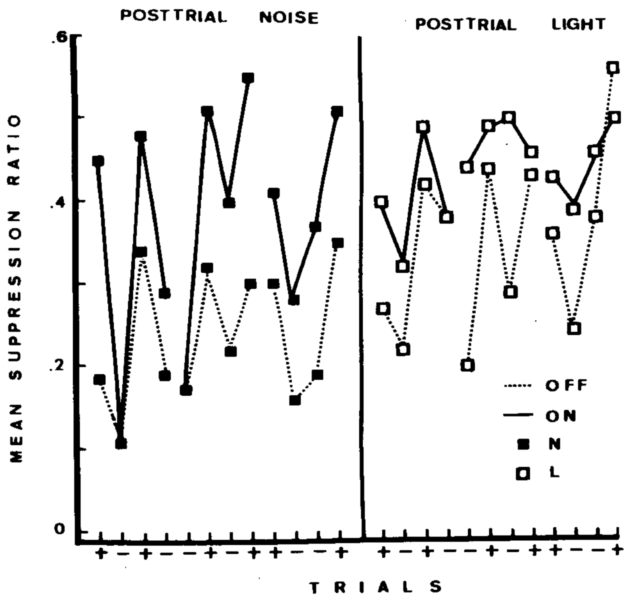

Figure 3. Course of posttrial barpress suppression across the 12 trials of testing. Reinforced trials are denoted by "+," and nonreinforced trials by "−." Trials are shown in the order in which they were presented.

First, rats previously trained off-line tended to freeze more than rats previously trained on-line in every period (B, D, and A) on both reinforced and nonreinforced trials. This tendency was not significant in the B periods, however, or in the A period on reinforced trials, but it was significant in both D periods and the A period on nonreinforced trials [$Ts(16) \geq 319$, $ps < .05$].

Second, as was the case during Pavlovian training (left panel Figure 2), the rats trained on-line with noise tended to freeze more during the CS than did their counterparts trained with light. The figure suggests that this effect was similar in magnitude on both reinforced and nonreinforced trials, as would be expected; however, the effect attained statistical significance only on the nonreinforced trials [$T(8) = 48.5$, $p < .05$]. A modality effect was also obtained in the A period on nonreinforced trials; here, again, the rats trained with noise froze more than those trained with light [$T(16) = 195.5$, $p < .01$].

Third, there was more freezing after nonreinforced trials than after reinforced trials. This US-omission effect was present to some extent in all four groups of the experiment. However, an analysis of change scores (percent freezing after nonreinforced trials minus percent freezing after reinforced trials) indicated that the US-omission effect on freezing was significantly greater for rats trained with noise than for those trained with light [$T(16) = 188$, $p < .01$]. Thus, the effect of US omission on freezing was similar to the effect of US omission on barpress suppression.

DISCUSSION

The present experiment sought to answer two questions: (1) Why does posttrial barpress suppression weaken with training? (2) Why is there more posttrial suppression following nonreinforced trials than following reinforced trials (US-omission effect)? With regard to the first question, the experiment sought to provide a crucial test between two hypotheses. According to the conditioned inhibition hypothesis, posttrial suppression weakens because the posttrial temporal stimuli predict safety rather than danger. According to the shock-as-S^D hypothesis, the shock comes to serve as an S^D for barpressing because food is usually available following a long bout of suppression evoked by the CS. The conditioned inhibition hypothesis anticipates that, following a long series of conditioning trials, subjects should show equally weak posttrial suppression regardless of whether conditioning previously was conducted on-line or off-line. For both groups, posttrial temporal stimuli should inhibit fear. The shock-as-S^D hypothesis, however, anticipates weak posttrial suppression only in rats trained on-line, for only these rats could conceivably learn that shock predicts the availability of food. The results were that, on our first test trial, posttrial suppression was, indeed, significantly stronger in the rats trained off-line than in the rats trained on-line. Thus, the results appear consistent with the shock-as-S^D hypothesis and inconsistent with the conditioned inhibition hypothesis. Unfortunately, however, an unanticipated complication makes it imprudent to give either hypothesis more credence than the other. Thus, at the outset of the experiment, we did not anticipate that, on the test trials, the rats previously trained off-line would freeze significantly more during the CS than would those previously trained on-line. Since CS-elicited freezing was stronger in the off-line rats, it might be more likely to persist into the posttrial interval despite the activating effects of shock. Such persistence of CS-elicited freezing would cause more posttrial barpress suppression on test in the off-line rats, thus producing the same results anticipated by the shock-as-S^D hypothesis.

The most obvious way to check this freezing hypothesis would be to see if on Test Trial 1 there was indeed more posttrial freezing in the off-line rats than in the on-line rats. However, our scoring techniques permitted us to observe only three-eighths of the rats on that trial. The best we can do, therefore, is to examine the aggregate measure of posttrial freezing shown in the right-hand panel of Figure 2. Here, on reinforced trials, we see a nonsignificant tendency for more posttrial freezing in the off-line rats. The freezing hypothesis cannot be lightly dismissed, however, because of the lack of a significant difference. It is likely that barpress suppression is more sensitive to group differences in freezing than is our observational measure; the reason is that our measure was a very stringent one: if a rat was crouched stock still but was slowly moving its head from side to side, it was scored as active. If this behavior, which is quite common during CSs, had been more likely in the posttrial period for the off-line rats, then it could have contributed to more posttrial barpress suppression without contributing to differences in posttrial freezing.

Because of the unanticipated confound between the amount of exposure to shock as an S^D and the amount of CS-elicited freezing on test, the present results in our view do not provide a clear answer to the question of why posttrial suppression weakens with training. At most, they seem to show only that the on-line vs. off-line method of answering this question—a method that seemed eminently reasonable—is probably not up to the task.

The results do, however, seem to provide a clear answer to our second question: why is there more posttrial suppression following nonreinforced trials than following reinforced trials (US-omission effect)? The results support the suggestion (Ayres & Vigorito, 1984) that on nonreinforced trials the freezing elicited by the CS is not disrupted by the US and so persists into the posttrial interval. This interpretation anticipates that if a CS in one modality were to produce more freezing than a CS in another modality, the US-omission effect would be greater for the CS that produced more freezing. The more a CS tends to evoke freezing, the more freezing should persist into the posttrial interval when not disrupted by a US. In the present study, the noise evoked more freezing than did the light, and, as expected, the US-omission effect was greater for the noise than it was for the light.

The present study, in addition, also makes several other contributions. First, it confirmed the observation that posttrial barpress suppression does decline significantly with training but showed (Figure 1) that this effect occurred with a noise CS but not with a light CS. One interpretation of this result is that the light and noise elicit different behaviors, which occur after US delivery and differentially affect posttrial barpress suppression. This possibility has important methodological implications for those investigators wishing to use posttrial barpress suppression as a measure of US effectiveness (see, e.g., LoLordo & Randich, 1981). Posttrial barpress suppression cannot be a pure measure of US effectiveness because it is complicated, apparently, by CS-specific behaviors that occur after US delivery.

Second, even though the noise elicited more freezing than did light, barpress suppression during the two stimuli was very similar (see, e.g., lower curves of Figure 1). This can only mean that the light elicited other behaviors, incompatible with barpressing, that compensated for the lack of freezing. Our measure did not permit any statement about what these other behaviors might be; informally, however, it seemed to us as though the light elicited more rearing (cf. Holland, 1979).[2] This finding, that the light and noise elicited similar levels of barpress suppression whereas the noise controlled more freezing, is directly relevant to the discussion of modality differences by Sigmundi and Bolles (1983). Finding that their noise elicited more freezing, Sigmundi and Bolles wondered whether the noise was better conditioned or whether noise and light controlled defensive behaviors that differed in form. On the basis of theoretical considerations about the competition between context cues and discrete CSs (Rescorla & Wagner, 1972), they argued that if the light was more poorly conditioned, then the context cues would be more strongly conditioned in rats trained with light than in those trained with noise. Differences in context conditioning would be reflected in differences in pre-CS freezing. Since there were no such differences in their study (cf. present Figure 2), Sigmundi and Bolles considered the possibility that the two CSs were equally conditioned but elicited different forms of defensive behavior. They then speculated on reasons why the form of the defensive responses controlled by light and noise might differ. To the extent that the similar levels of barpress suppression to noise and light in the present work can be taken as evidence for similar levels of conditioning, our results resemble those of Sigmundi and Bolles and help justify their speculations. Moreover, taken together with the findings of Sigmundi and Bolles, our results may have relevance for other recent work (Jacobs & LoLordo, 1980). In a conditioned avoidance task, Jacobs and LoLordo found that a loud tone served as an effective danger signal but was ineffective as a safety signal. A light CS had the opposite properties. Jacobs and LoLordo interpreted their light-tone differences in terms of differences in associative strength. Our results suggest that performance differences, that is, differences in behavioral topographies controlled by lights and tones, may have contributed to their findings.

Third, during Pavlovian training, there was much more freezing in rats trained off-line than in rats trained on-line. Furthermore, rats trained off-line froze so much during pre-CS periods that, in these rats, it was difficult to see any evidence of stimulus control by the CS. For example, the left panel of Figure 2 shows that for the rats trained off-line with the light CS, there was actually slightly more freezing before the CS than during it. Similarly weak evidence of stimulus control of freezing in rats trained off-line can be seen in the results presented by Sigmundi and Bolles (1983). Note, however, that, in rats trained on-line in the present study, the evidence for stimulus control of freezing by the CS was excellent: freezing was confined almost exclusively to CS periods.

Fourth, although the on-line and off-line rats were exposed to identical Pavlovian contingencies during Pavlovian training, the off-line rats showed more CS-elicited freezing and barpress suppression when tested on-line than did the rats previously trained on-line. Although this is the unanticipated result that confounded our attempt to test the shock-as-S^D hypothesis against the inhibition hypothesis, it is an interesting result in its own right. It is notable that it occurred despite the generalization decrement that should have affected the off-line rats following the introduction of the barpress-food-getting task. As one of the more robust effects in the present study, it demands an explanation. One possibility is that the off-line rats froze more during Pavlovian training simply because they had nothing else to do, and that this response to the situation became habitual and carried over to the test even when they were given something else to do. Another possibilty is that the rats trained on line were so distracted by the barpress task that they were less able to attend to Pavlovian relationships. Another possibility is that the food presentations that occurred for the rats trained on-line "counterconditioned" appetitive emotional states (hope), which weakened any aversive emotional states (fear). Another possibility is that during on-line sessions rats assumed postures appropriate for barpressing, postures that differed from those they assumed when not barpressing during off-line sessions. Perhaps these differences in posture affect their reception of shock. Another possibility is that by the time of testing, the on-line rats had received 9 more days of operant training than had the off-line rats. Perhaps the operant baselines of the on-line rats were, in some sense, stronger and less subject to disruption. With regard to this last interpretation, however, we know of no direct evidence in the conditioned suppression literature to suggest that 14 h of VI training produces a baseline less subject to the suppressive effects of CSs than does 5 h of VI training. Furthermore, those studies that have deliberately attempted to manipulate the "strength" of baselines by varying the value of the incentive used to maintain them have shown either no effects (Ayres, 1968; Ayres & Quinsey, 1970) or effects that were weak at best (Hancock & Ayres, 1974). Thus, of the interpretations we have considered for our on-line vs. off-line differences, the "baseline strength" interpretation is not only the least interesting, but probably also the least likely to be correct.

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NOTES

1. We thank Joan C. Bombace for reminding us of this idea.

2. On reading this passage, a colleague raised the following question. "If the light CS elicits defensive behaviors other than freezing, shouldn't those behaviors persist beyond CS termination (the way freezing does)? If they did, wouldn't they interfere with barpressing, and therefore shouldn't the US-omission effect be as great for light as for noise?" We can't answer this question with authority, because we don't know exactly what behaviors the light actually elicits. However, we are proposing that freezing is more persistent than are these unknown behaviors. In a situation in which rats were not barpressing for food, Bolles and Riley (1973) found that freezing was disrupted by shock but that, when it resumed, it persisted for about 15 min unless disrupted by another shock. Bolles and Riley suggested that freezing was a "peculiar respondent" because, when elicited, it follows a "unique time course" (p. 275). Our assumption is that the persistence of freezing is not shared by the defensive behaviors elicited by our light.

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