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Latent Inhibition of a CS During CS–US Pairings

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In each of three experiments rats were trained by the conditioned-emotional-response technique with a conditioned stimulus (CS) predicting a relatively weak shock, the unconditioned stimulus (US). In the second stage of training the intensity of the shock was increased, and it was found that subjects for whom the same CS was used in both stages acquired further suppression less readily than subjects that experienced a new CS in the second stage. The implication of these results for theories of attention and for theories of habituation is discussed. It is suggested that associations formed by the test CS during the first stage of training reduce the readiness of the stimulus to enter into new associations, either because an association between the stimulus and the context reduces further processing of the stimulus or because the association between the test stimulus and the weak shock attenuates the formation of an association with the stronger shock.

In the article preceding this one (Pearce & Hall, 1979) we presented evidence suggesting that a stimulus will lose associability as a result of repeated presentation even when the stimulus is presented in a predictive relationship with reinforcement. Our results can be accommodated by Mackintosh's (1975) theory of attention as well as by theories explicitly concerned with the way in which stimuli may lose associability, for example, Wagner's (1976) theory of habituation. The experimental design used in the experiments reported in the preceding article was quite complex, and the experiments reported in this study constitute a much simpler and more direct test of the suggestion that latent inhibition will occur to a stimulus even when that stimulus is a conditioned stimulus (CS) predicting the occurrence of an unconditioned stimulus (US). This new design also allows us to investigate the extent to which habituation of the unconditioned response to a CS is modified by CS-US pairings. Further, it may be possible to choose, on the basis of our new results, between the alternative accounts of our previous findings.

All three experiments in this study used the same basic technique. Rats were first trained in a conditioned-emotional-response (CER) paradigm with a CS predicting a weak electric shock. They were then trained with the same CS followed by a more intense US. If the shock used in the first stage of training is sufficiently weak, suppression should not be total, and by increasing shock intensity it should be possible to observe further learning taking place in the second stage.

It is to be expected that this further learning will occur quite rapidly if the first stage of training with the weak shock has already endowed the stimulus with some associative strength as a signal for shock. According to current theories of classical conditioning (e.g., Rescorla & Wagner, 1972), the effect of increasing the intensity of the US is simply to increase the asymptotic associative strength that the CS can achieve. Prior training with a weak shock means that the stimulus will already be partway to this

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new asymptote, which should therefore be reached after relatively few further training trials. On the other hand, our own work suggests, and the theory of Wagner (1976) predicts, that pretraining with the CS can cause it to lose associability. The presentation of the weak shock during the first stage of training may attenuate the loss of associability but should not prevent it altogether. For this reason, therefore, learning should proceed slowly when the stronger shock is introduced. Given that the stimulus may already have acquired some associative strength in the first stage of training, slow learning during the second stage will be particularly strong evidence that a loss of associability has occurred.

Mackintosh's (1975) theory makes a different prediction This theory maintains that a stimulus that predicts a reinforcer more accurately than any other event will actually gain in associability. If, therefore, the weak shock used in the first stage of training in our experiments is an effective reinforcer and a CS-US association is formed, the increased associability of the stimulus should produce very rapid learning when the increase in shock intensity allows further learning to occur.

Experiment 1

In this experiment, rats in the L group were trained with a light signaling a weak shock (for a large number of trials to ensure that any change in associability that might occur would be complete) and were then given a few trials with the light signaling a stronger shock. Subjects in the T group received identical training except that in Stage 1 a tone was used to signal the weak shocks; these animals thus had the same experience of shock and differed only in that the light was completely novel at the beginning of the second stage. The L group should show some conditioned suppression at the start of Stage 2, but, if the light does lose associability during Stage 1, they may acquire further suppression more slowly than the group pretrained with the tone. After Stage 2 training, all subjects received a series of nonreinforced test trials with the light and were then trained with the tone predicting strong shock. In this case it was the L group that had not previously experienced the to-be-conditioned stimulus, and we predicted that learning would proceed rapidly in this group relative to the T group.

Method

Subjects. The subjects were 16 male hooded (Lister) rats about 4 months old at the start of the experiment. They were maintained throughout at 80% of their free-feeding weights. They had previously undergone training in a study of free-operant responding (Pearce & Hall, 1978, Experiment 1), in which they had learned to press a response lever for food and had received 30 sessions with responding reinforced on a variable-interval 60-sec (VI 60) schedule. On 20 of these sessions the rats had experienced an occasional 200-msec flash of light from a bulb fixed over the lever. This stimulus was not used in the experiment reported here.

Apparatus. Four identical Skinner boxes (Campden Instruments, Ltd.) were used. Each was equipped with a single response lever adjacent to a recessed food tray to which 45-mg food pellets could be delivered. The floor was composed of steel rods that could be electrified by a Grason-Stadler shock generator (Model 700). The roof of each box consisted of a sheet of white translucent plastic, above which was fixed a 30-W strip light that was operated at 65 V to supply the light stimulus. A loudspeaker mounted on the rear wall of the box was used to present a tone of 4000 Hz at an intensity of 82 dB re 20 $\mu N/m^2$, the intensity being measured close to the lever. Each box was housed in a sound- and light-resistant chamber that contained an exhaust fan that provided background masking noise of 53 dB.

Procedure. Because the subjects had already received extensive experience of a VI schedule, little preliminary training was required. They were given three daily 1-hr sessions with lever pressing reinforced on a VI 60-sec schedule before the first of the four stages of training was begun. The VI schedule remained in force throughout the experiment.

Stage 1 consisted of 12 daily sessions of CER training. Each session lasted 1 hr and included six conditioning trials, the interval between the onset of adjacent trials being 10 min and the first trial occurring 7.5 min after the beginning of the session. Each trial lasted 90 sec, and for half the subjects chosen at random (the L group), the stimulus presented was the light; for the remainder (the T group), it was the tone. Every trial ended with an electric shock, which for the first 2 days of training was of .5 mA for .2 sec. This shock,

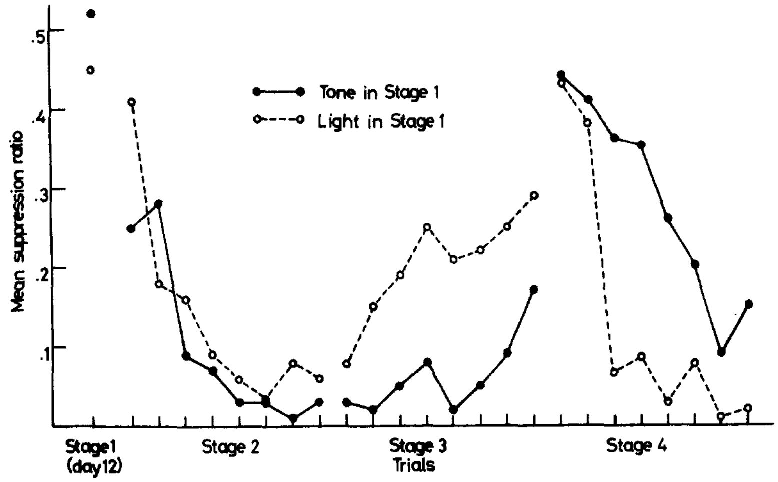

Figure 1. Experiment 1: group mean suppression scores for the last day of Stage 1 (weak shock training), Stage 2 (light and strong shock), Stage 3 (extinction trials with the light), and Stage 4 (tone and strong shock). (T = tone; L = light.)

although relatively weak, was enough to produce substantial suppression of responding after only 2 days, and accordingly, the shock intensity was reduced to .3 mA for the remaining 10 days of Stage 1. Conditioning was assessed in terms of a suppression ratio having the form A/(A + B), where A represents the rate of responding during the CS, and B represents the rate during the 90-sec period immediately preceding stimulus onset.

In Stage 2 all subjects received training in which the light stimulus was followed by a 1-mA, .5-sec shock. Sessions lasted for 40 min and contained two trials beginning after 12 and 35 min. There were four such sessions.

The two sessions of Stage 3 were 1 hr long and contained four trials beginning at the following intervals after the start of the session: 10.5, 21, 31.5, and 42 min. On these, the light stimulus was presented but was not followed by shock. This stage of training was included to increase the likelihood of detecting a difference between the two groups; 4 days of training in Stage 2 proved to be enough to produce almost total suppression in the presence of the light in both groups, and it was hoped that a difference in associative strength between the two groups would be revealed by a difference in the rate at which responding recovered when the shocks were discontinued.

Stage 4 was similar to Stage 2; it differed only in that conditioning trials were given with the tone preceding the 1-mA, .5-sec shock.

Results

Data were recorded on the final day of Stage 1 training. On this day the T group showed a mean response rate during the prestimulus periods of 24.51 responses per minute and the L group, 36.15 responses per minute. These scores differed significantly, $t(14) = 2.42$, $p < .05$. Figure 1 shows suppression scores for this day; responses emitted on all trials were pooled before the ratio was calculated for each subject. It is apparent that the 12 days of conditioning with the weak shock were not effective in producing suppression in the T group. The L group, however, showed slight but significant suppression in the presence of the light, all but one of the animals having suppression ratios of less than .50 (binomial test, $x = 1$, $p < .05$, one-tailed). This difference in suppression presumably reflects a difference in salience between the stimuli.

During Stage 2 the overall mean response rates during prestimulus periods were 23.37 responses per minute in the T group and 32.65 responses per minute in the L group, a difference that fell short of statistical significance, $t(14) = 1.85$, $p > .05$. Figure 1 shows the suppression scores for each trial of this stage in which the light signaled the stronger shock. On the first trial, before the new shock intensity had been experienced, Group L showed much the same level of suppression as was seen at the end of Stage 1. Group T, for whom the light was a novel stimulus, showed a marked unconditioned suppression effect. This difference was reversed on the second trial, but thereafter, Group T showed consistently more suppression than Group L. Statistical analysis confirms these impressions. An analysis of variance carried out on the Stage 2 data shown in Figure 1 reveals no significant effect of groups, $F(1, 14) = 1.97$, but a significant effect of trials, $F(7, 98) = 27.94$, $p < .01$, and a significant interaction between these two factors, $F(7, 98) = 3.32$, $p < .01$. Analysis of simple main effects showed that a significant difference existed on Trial 1, $F(1, 112) = 12.50$, $p < .01$, and on Trial 2, $F(1, 112) = 4.90$, $p < .05$, but on no other trials.

The mean prestimulus response rates during Stage 3 were 24.05 responses per minute in the T group and 32.86 responses per minute in the L group, and they did not differ significantly, $t(14) = 1.73$, $p > .01$. Figure 1 shows that the T group was slow to extinguish suppression to the light in comparison with the L group. Analysis of variance showed significant effect of trials, $F(7, 98) = 7.63$, $p < .01$, a significant effect of groups, $F(1, 14) = 10.51$, $p < .01$, but no significant interaction, $F(7, 98) = 1.59$, $p = .15$.

In Stage 4, the mean prestimulus response rates (24.25 responses per minute in the T group and 28 responses per minute in the L group) did not differ significantly, $t(14) = 0.61$. Neither group showed much suppression to the tone on the first day of conditioning, but thereafter, suppression developed more quickly in the L group, which had experienced only the light in the preceding stages of training. There was a significant effect of trials, $F(7, 98) = 24.86$, $p < .01$, a significant effect of groups, $F(1, 14) = 8.29$, $p = .01$, and a significant interaction between these two factors, $F(7, 98) = 3.09$, $p < .01$.

Discussion

The repeated presentation of a neutral stimulus in isolation is known to have two effects. First, this procedure can result in a decrement in the strength of the unconditioned responses elicited by that stimulus (e.g., Whitlow, 1975). Second, the stimulus may lose associability—the latent-inhibition effect (Lubow & Moore, 1959). These effects were observed in the present study in which the neutral stimulus was presented, not in isolation, but in a predictive relationship with electric shock.

An example of the former effect can be seen by comparing the performance of the two groups on the first trial of Stage 2, before either had experienced the light in association with the strong shock. The light was novel on this trial for Group T and the moderate level of suppression that it evoked can be taken as a measure of the unconditioned properties of the stimulus. That the light produced significantly less suppression in Group L on the same trial is an indication that the repeated presentation of this stimulus during the Pavlovian conditioning of Stage 1 resulted in the weakening of its unconditioned properties. It should be noted that a similar effect was not observed with the tone at the beginning of Stage 4 training. This result was probably due to the fact that the unconditioned suppressive effects of this stimulus when novel (Trial 1, Stage 4, Group L) are much less than those of the light stimulus. A similar difference between the unconditioned effects of auditory and visual stimuli has been reported by Donegan, Whitlow, and Wagner (1977) and Hendersen (1973).

An example of the second, latent-inhibition, effect can be seen in the latter stages of the experiment. Although Stage 2 failed to detect a slower rate of learning to the light in Group L than in Group T, a difference did emerge between these two groups during Stage 3. The more rapid rate of extinction in Group L shows that conditioning with the large shock was less effective for this group and indicates, therefore, that the experience of light–weak shock conditioning trials reduced the associability of the light during Stage 1. Similarly, the slower rate of conditioning in Group T during

Stage 3 is evidence of a loss in associability by the tone as a consequence of the training given in Stage 1. The reasons for the failure to detect a loss of associability by the light during Stage 2 are obscure. It is possible, however, that any differences during this stage were masked by "ceiling" effects, imposed by the ability of the CER procedure to demonstrate differences between groups only up to the point of maximum response suppression.

Before accepting that these results demonstrate a decline in the associability of the tone and the light as a result of their initial conditioning treatment, two alternative explanations should be considered. First, it is possible that the difference between the two groups during the extinction trials of Stage 3 represents a persistence of the unconditioned suppression shown by the T group on the first trial of Stage 2. This is unlikely, because the unconditioned effect seemed to have dissipated by the second trial of Stage 2. On this trial the T group evidenced slightly less suppression than did the L group, a pattern of scores to be expected given that the L group had been pretrained with the light signaling shock. The second alternative account (which can only be applied with any force to the results of Stage 4) is based on the fact that the tone acquired no capacity to suppress responding in Stage 1. It could be argued that no association was formed between tone and weak shock and that, instead, the background stimuli acquired associative strength (Odling-Smee, 1975). The fact that the T group showed a relatively low prestimulus response rate in Stage 1 (i.e., a low rate of response in the presence of the background stimuli) is consistent with this suggestion. It might then be argued that the existence of an association between background stimuli and shock blocked conditioning (Kamin, 1969) in subsequent stages of training, and thus slowed the rate of learning in the T group. We can reject this argument, however, on the grounds that slow learning was found only in the last stage of the experiment; a blocking effect would also have retarded learning in Stage 2, where, in fact, the T group learned readily.

This experiment has successfully demonstrated that a stimulus presented in association with reinforcement will suffer a loss of associability and (in the case of the light) that habituation of the unconditioned response will occur. What is not clear, however, is that the stimulus in question entered into an association with the reinforcer during Stage 1 training. It is possible that the intensity of the shock used in Stage 1 was insufficient for it to function as an effective reinforcer, and it could thus be argued that our results are simply a further demonstration of latent inhibition in associatively neutral stimuli. The remaining two experiments take up this point: Experiment 2 compares the effects of the Stage 1 training procedure with those produced by simple latent-inhibition training; Experiment 3 investigates the effects of giving Stage 1 training with a relatively strong shock.

Experiment 2

This experiment examines the acquisition of suppression to a tone signaling strong shock in three groups of subjects that differed in their prior training. Two groups paralleled those of Experiment 1. The T group was trained initially with the tone signaling a weak shock; the L group was trained with a light signaling the weak shock. We hoped to replicate the main result of Experiment 1 by finding more rapid acquisition in the second stage by the subjects experiencing a change of stimulus between the two stages. The procedures used for these two groups differed from those used in Experiment 1 only in three minor ways: First, the tone rather than the light was the stimulus for the second stage of training; second, the intensity of the tone was increased in an attempt to ensure that significant suppression would occur to it during the first (weak shock) stage; finally, a slightly less intense shock was used in Stage 2 to ensure that the rate of learning would not be so rapid as to obscure differences between the groups. The third group of subjects constituted a latent-inhibition

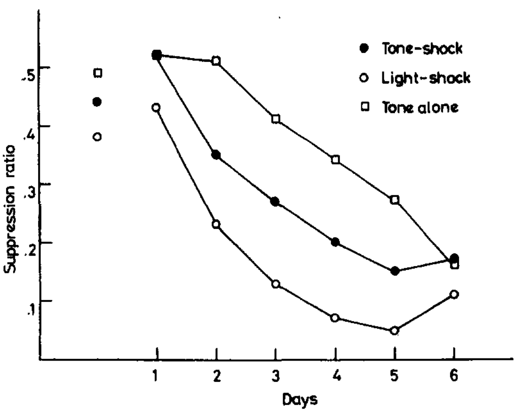

Figure 2. Experiment 2: group mean suppression scores for the last day of Stage 1 and the 6 days of Stage 2 (tone and strong shock). (The legend refers to the training given in Stage 1. The learning curve for the Tone-alone group is the mean of 5 subjects.)

(LI) group and received presentations of the tone alone in Stage 1. These subjects should develop no conditioned suppression during Stage 1, and comparison with the performance of the T group should give a measure of the influence of shock presentations on the latter group. Comparison of the two groups in Stage 2 will reveal the extent to which latent inhibition is attenuated by pairing the stimulus with a reinforcer.

Method

The subjects were 24 male hooded rats maintained as in Experiment 1. These too had previously been used in a study (Pearce & Hall, 1978, Experiment 2) in which, after magazine training and response shaping, they had received extensive experience (20 sessions) of a simple VI 60 schedule. On five of these sessions they had received occasional brief flashes of light from the bulb above the lever.

The apparatus was that used in Experiment 1. The intensity of the tone was increased to 85 dB re 20 $\mu N/m^2$.

After 5 days of VI 60 training, the rats were divided at random into three groups of eight. All received 11 sessions of Stage 1 training. The T group received six trials each session with the tone followed by the weak shock, the L group received the overhead light followed by the weak shock, and the LI group received trials with the tone alone. The specific procedures used were those described for Experiment 1 except the shock intensity was maintained throughout at .4 mA for .2 sec. There were 6 sessions of Stage 2 training in which for all subjects the tone signaled the stronger shock, which in this experiment was .8 mA for .5 sec.

Results

The response rates of the three groups during prestimulus periods on the last day of Stage 1 showed no significant differences. The rates were 27.04 responses per minute in the T group, 24.06 responses per minute in the L group, and 21.77 responses per minute in the LI group, $F(2, 21) = 1.36$, $p > .2$. Figure 2 shows the suppression ratios of the three groups on the last day of Stage 1. Both the T and L groups gave evidence of suppression; in each group all but one of the subjects had ratios of less than .50 (binomial test, $x = 1$, $p < .05$, one-tailed). In the LI group all but two of the subjects had ratios greater than .50, suggesting a slight (although, by the binomial test, nonsignificant) tendency for the tone to potentiate responding ($x = 2$, $p > .14$).

On the first trial of Stage 2 the LI group again showed no suppression, with a ratio of .51, whereas in the T group the mean score rose to .51. The L group, which experienced the tone for the first time on this trial, had a mean suppression ratio of .40 and showed significant suppression (binomial test, $x = 1$, $p < .05$, one-tailed).

During Stage 2 all three groups came to suppress responding in the presence of the tone (see Figure 2). A difficulty arose in that three subjects in the LI group (a group that had not previously experienced electric shock) showed complete suppression after 3 days of training and responded neither during the tone nor during the prestimulus period. It is not possible to compute a meaningful suppression ratio for these animals, and accordingly, the mean scores for the LI group in Figure 2 are based on the performance of the remaining five subjects in this group. These data were then analyzed by nonparametric techniques. A mean suppression ratio over all 6 days was computed for each subject, and these scores were subjected to a nonparametric analysis of variance that revealed a significant difference among the three groups (Kruskal-Wallis test, $H = 9.21$, $p = .01$). Subsequent tests showed the L group to be significantly more suppressed than the T group (Mann-Whitney test, $U = 13.5$, $p < .05$, one-tailed) and the T group to be significantly more suppressed than the LI group ($U = 8$, $p < .05$). The LI and L groups differed significantly ($U = 1$, $p < .01$).The need to exclude animals from the LI group was unfortunate, but the occurrence of complete suppression in these subjects can be taken as evidence that conditioning was severely retarded in the LI condition. We assume that complete suppression results from the animal's forming an association between background cues and shock, which itself reflects a failure to form an association between the tone and shock.

The overall mean response rates during the prestimulus periods of Stage 2 were 26.77 responses per minute in the T group, 24.06 responses per minute in the L group, and 23.38 responses per minute in the LI group. These scores did not differ significantly (Kruskal-Wallis test, $H = .41$).

Discussion

This experiment differed in a number of details from Experiment 1, but comparison of the Stage 2 performance of the T and L groups confirms the essential findings of that experiment: Preexposure to a stimulus, even when it is used to signal the occurrence of an electric shock, will result in the reduction of any unconditioned suppression that the stimulus might evoke and will retard the subsequent rate of learning involving that stimulus. It shows, in addition, that exposure to the stimulus alone (Group LI) produces an even more severe retardation of later learning. The differing performances of the T group and the LI group in Stage 2 makes it clear that the Stage 1 shock was at least detected by the T group animals, although there may still be doubt as to whether the tone acquired any associative strength in the T group.

There are two possible explanations available for the differences in Stage 2 performance of the LI group and the T group. The first assumes that in the T group the tone acquired associative strength during Stage 1 but, at the same time, suffered the same loss of associability it suffered in the LI condition. Both of these groups might therefore be expected to acquire suppression less readily than the L group, for whom the test stimulus was novel, but the effect would be compensated for, to some extent, in the T group by the small amount of associative strength already governed by the tone. This account is made less plausible by the fact that the tone evoked no suppression in the T group on the first trial of Stage 2. It may therefore be that the suppression shown on the last day of Stage 1 was the residue of an unconditioned response to the tone (that the tone used in this experiment did evoke unconditioned suppression is shown by the performance of the L group on Trial 1 of Stage 2) that had finally become habituated by the first trial of Stage 2.

The alternative explanation of these results derives from some recent work on habituation by Wagner and his collaborators (Wagner, 1976) and raises the possibility that the role of the shock during Stage 1 training for the T group might be to diminish the extent to which the tone loses associability—that is, to protect it from habituation. It has been shown (Wagner, 1976; Whitlow, 1975) that the habituation of an unconditioned response to a tone is attenuated when some different, distracting stimulus occurs shortly after the target stimulus. This attenuation is seen both during the training period and when, as in our experiment, a test session is given after a longer time interval (Whitlow & Wagner, as cited in Wagner, 1976). Wagner explains the long-term habituation effect as follows: When a stimulus is presented repeatedly, alone, an association is formed between the stimulus and the context in which it occurs. As a result, when the animal experiences the context again, the stimulus is, in Wagner's terminology, "primed into short-term memory." Habituation is accounted for by assuming that the likelihood of a stimulus being processed is diminished to the extent that its representation has already been primed into short-term memory. Protection from habituation is thought to occur because of a reduction in the strength of the association between the context and the target stimulus. The strength of this association depends upon the length of time that the target stimulus and contextual stimuli exist together in short-term memory; one effect of presenting a distractor is to take up some of that system's processing capacity, thus reducing the amount available for processing the stimulus and the context.

Wagner extends his theory of habituation to include the phenomenon of latent inhibition with the suggestion that the same processes that cause a loss of the unconditioned response to a stimulus also produce a loss of associability by the stimulus. Thus for our current results it can be argued that for the LI group an association will be formed between the Skinner box and the tone during Stage 1. In Stage 2 a representation of the tone will be primed into short-term memory, thus diminishing the chances of the stimulus and the bigger shock being processed together. As a result, conditioning will proceed slowly. A similar analysis can be applied to the performance of the T group. In this case too, an association will be formed in Stage 1 between context and tone, but the retardation of learning in Stage 2 will not be as marked for two reasons. First, the pairing of the tone with a weak shock may already have endowed the tone with some associative strength as a signal for shock. Second, the weak shock in Stage 1 will act as a distractor and will reduce the strength of the context–tone association. Finally, the L group will have no context–tone association after Stage 1 training and will therefore condition quickly to the novel tone in Stage 2.

The extension of this account of habituation to cases of latent inhibition receives support from the work of Lubow and his collaborators. Lubow, Schnur, and Rifkin (1976) reported experiments in which rats were exposed to a series of tones and then received training with the tone predicting a shock; conditioning was assessed by the extent to which presentation of the tone disrupted a water-licking response. Lubow et al. (1976) convincingly demonstrated latent inhibition using this procedure and showed that the effect was attenuated when a brief light was presented immediately after the tone in the first stage of training. According to Wagner's account, the light stimulus acted as a distractor.

It should be noted that Lubow's own interpretation of his findings (Lubow, Alek, & Arzy, 1975; Lubow, Schnur, & Rifkin, 1976), although it makes many of the same predictions as Wagner's theory, is rather different. He argues that when a stimulus is first presented, it evokes an "attentional response" that is maintained when the stimulus is followed by an unconditioned stimulus or by any environmental change but is diminished when it is not. Lubow refers to this diminution as the conditioning of inattention to the stimulus. This theory, too, can accommodate the current results, but there is one minor problem. Implicit in Lubow's theorizing is the suggestion that the attentional response will be maintained at full strength when the stimulus is followed by a conventional reinforcer like electric shock, whereas our results show that latent inhibition may occur in this case, too. It is a simple matter to assume, however, that a very weak shock, like that used in our Stage 1 training, will be no more effective than a supposedly neutral stimulus, like the onset of a light, in maintaining the attentional response.

Experiment 3

Experiments 1 and 2 have demonstrated that a stimulus presented in association with shock will lose associability. At first sight this finding seems to contradict the assumption made by many theories of attention that a stimulus that has been established as a good predictor of reinforcement actually acquires extra associability (Mackintosh, 1975). In order to maintain the assumption that CSs gain in associability as they acquire associative strength during conditioning, it would be possible for Mackintosh to argue that in the experiments reported in this article, the shock used was too weak to support the formation of a CS-US association. In this case, our Stage 1 training would be functionally equivalent to simple latent-inhibition training, and no increase in the associability of the stimulus would be expected.

It is of some interest, therefore, to investigate whether the loss of associability that we found in our previous experiments by a stimulus paired with shock will occur when the US intensity is such as to ensure that the stimulus in question becomes properly established as a CS for shock. According to Mackintosh's theory, the CS will gain associability during Stage 1, and this process, coupled with the fact that the CS will already possess some associative strength at the beginning of Stage 2, should produce very rapid subsequent learning.

In Experiment 3, therefore, rats were trained with a shock of .5 mA for .5 sec in Stage 1; the shock intensity was increased to 2 mA in Stage 2. Training in the first two stages was given off the baseline (i.e., with the levers removed from the boxes), and performance was monitored in a Stage 3 extinction test. It was hoped that differences between groups in the associative strength of the tone would be evidenced by differential rates of recovery from suppression during extinction.

Carrying out Stages 1 and 2 off the baseline allows us to test an alternative explanation for the results of the previous experiments that can be derived from the work of Church (1969). Church reported experiments that investigated the effects of relatively mild noncontingent electric shocks presented to rats bar pressing for food upon the response suppression produced by stronger response-contingent shocks in a second stage of training. He found that exposure to the weaker shock reduced the amount of suppression seen during the punishment phase, an effect that looks like adaptation to the shock. Clearly, adaptation cannot account for the difference observed between the two groups in our Experiment 1 or between the T group and the L group in Experiment 2, because all of these subjects had equal experience of shock. However, Church himself rejects the notion of adaptation and suggests instead that rats exposed initially to weak shocks learn to respond at a given (fairly high) rate in the presence of shocks, and that making strong shocks contingent upon responding produces some suppression, but this is counteracted to some extent by the learned tendency to respond at a high rate in the presence of shocks. It is possible to construct a parallel explanation for the results of Experiments 1 and 2 of this study: Those rats that received the same stimulus in both the weak and strong shock stages of training might learn to respond at a fairly high rate in its presence in the first stage and then transfer this habit to the second stage. The outcome would be the slow acquisition of conditioned suppression by these animals in the second stage. According to this explanation, therefore, no transfer effect should be found when training is given off the baseline.

Method

The subjects were 32 naive male hooded rats maintained as in the previous experiments. After magazine training and response shaping, they received a 30-min session with reinforcement available on a VI 30-sec schedule followed by 6 45-min sessions of VI 60-sec. Twenty-four of the subjects were then chosen at random and divided into two equal groups, a T group and an L group. The levers were removed from the boxes, and these two groups received 13 daily sessions of Stage 1 training. Group T received four trials each day with the tone followed by a .5-sec shock of .5 mA. Sessions lasted 1 hr and trials occurred at 10-min intervals. Group L received identical treatment except that the stimulus used was the overhead light. In Stage 2 all subjects received 2 sessions in which the tone predicted a shock of 2 mA lasting .5 sec. There were two such trials in each 40-min session. On the next day the levers were replaced, and all animals received 1 hr of simple VI 60-sec to allow responding to recover. Stage 3 consisted of a single session during which the tone was presented four times in the absence of shock.

Although there can be little doubt that the .5-mA, .5-sec shock used in Stage 1 is an effective US

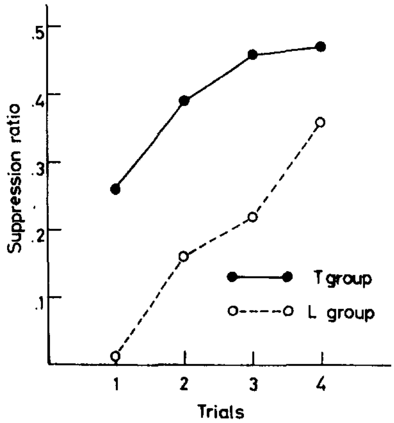

Figure 3. Experiment 3: group mean suppression scores for Stage 3 (extinction trials with the tone). (T group was trained with tone in Stage 1; L group was trained with light in Stage 1.)

with a stimulus as salient as our 85-dB tone (see, e.g., Kamin & Brimer, 1963), the remaining eight rats were used to give an empirical demonstration of this point. They were subjected to the same Stage 1 training as the T group, that is, 13 sessions with the tone and .5-mA shock. They were then given a recovery session, and in the next session they received four tone trials on the baseline with the tone followed by the .5-mA shock. On each of the next 3 sessions, the animals received four reinforced trials with the light stimulus and this same shock. The first of these 3 sessions was extended to 80 min and included six light trials, the first two being nonreinforced so that the unconditioned effect of the light might habituate.

The apparatus and procedural details not specified above were the same as employed in Experiment 2.

Results

The results of the group of animals used to assess the effectiveness of the .5-mA shock will be dealt with first. On the test session with the tone they showed consistent suppression with a mean suppression ratio of .38 (range: .26–.47). Suppression increased over the 4 test trials with the tone from a mean score of .45 on Trial 1 to .33 on trial 4, $t(7) = 2.20$, $p < .05$, one-tailed. Similarly, the amount of suppression shown to the light increased with reinforced pairings, the mean score for the first four reinforced trials being .48, for the next four, .42, and .31 for the final day's trials. There was a significant change in suppression between the scores on the first and last days, $t(7) = 4.21$, $p < .01$.

The baseline response rates of the T and L groups were closely similar. The mean response rate of the T group on the recovery session that preceded Stage 3 was 23.59 responses per minute; that of the L group, 25.84 responses per minute; and these rates did not differ significantly, $t(22) = 1.07$. The mean overall rates during Stage 3 were 25.38 responses per minute and 25.90 responses per minute for the T and L groups, respectively, $t(22) = .14$.

Figure 3 shows the course of extinction of suppression for these two groups. It is clear that the T group was less suppressed in the presence of the tone than the L group from the first trial and that this difference was maintained, diminishing only as the asymptote of .5 was reached. An analysis of variance showed a significant effect of trials, $F(3, 66) = 23.89$, $p < .01$, a significant effect of groups, $F(1, 22) = 16.11$, $p < .01$, but no significant interaction between these two factors, $F(3, 66) = 1.68$.

Discussion

The eight animals trained only with the .5-mA shock showed significant suppression on the test session with the tone, suggesting that this US was effective in endowing the tone with associative strength. That this suppression represents a conditioned effect and is not the result of an unconditioned effect being protected from habituation by the shock is indicated by the fact that suppression increased over the test trials. This increase in suppression may reflect the acquisition of further associative strength by the tone, or it may be that the suppression goverened by the tone was disrupted in the early trials by the change in conditions from training to testing. At any rate, it is not the pattern of results we should expect from an unconditioned effect that tends to be most marked on the first trial of any given day (Whitlow, 1975). The acquisition of a suppressive effect by the light confirms that the .5-mA shock was still an effective US at the end of Stage 1 training.

That the shock used in Stage 1 was an effective reinforcer does not require us to modify the explanation for our results that we developed in the discussion of Experiment 2. We can accept that, in the T group, the tone both acquired some associative strength and suffered a loss of associability. The retardation of Stage 2 learning produced by the latter effect was presumably enough to outweigh any facilitation produced by the former effect. In contrast, these results present a major difficulty for Mackintosh's (1975) theory of attention, which predicts that Stage 1 training with the tone should increase the associability of that stimulus and should thus facilitate the formation of the tone–shock association in Stage 2. It might be possible for Mackintosh to argue that the tone used in this experiment was so salient that no further increase in associability was possible. It remains difficult to explain, however, why a loss of associability was found.

General Discussion

Prior conditioning in which a stimulus predicts a small shock retards further conditioning when the same stimulus is used to signal a bigger shock. This finding accords with the general suggestion that when a stimulus loses novelty, it also loses the ability to enter into associations. Wagner's (1976) theory of habituation provides a plausible account of the mechanism by which this loss of associability may occur. It suggests that a stimulus, even when it predicts a reinforcer, will form an association with the context in which it is presented and that the existence of this association will reduce the capacity of the stimulus to form new associations. In this way our finding is treated as a special case of latent inhibition.

It should be noted that interpreting our results in this way leads to what, at first sight, seems to be a curious prediction about the course of acquisition of a conditioned response. If we accept that even during reinforced training a CS becomes less and less likely to be processed as its association with the context grows stronger, then we may predict that the conditioned response itself will diminish as conditioning proceeds. But that this does not occur in most cases of classical conditioning cannot be taken to disprove the theory. If we assume that a fully formed context–CS association does not totally prevent the CS from being processed, then some conditioned responding will always occur; and further, if the CS-US association continues to grow stronger after the context–CS association has reached asymptote, we are not likely to see a diminution in the strength of the conditioned response at any stage of training.

In conclusion, it should be added that it might be possible to develop a quite different explanation for our results from that described above by making use of the notion of associative interference. In interpreting our results we have followed Rescorla and Wagner (1972) in assuming that the difference between a weak shock and a strong shock should be expressed theoretically as an increase in the value of some parameter representing shock. It might be possible, however, to regard the two shocks as basically different events. In this case our results point to the conclusion that associating a stimulus with one event (always assuming that a CS-US association was indeed formed during Stage 1 training) reduces the ability of that stimulus to enter into an association with another event. It is of interest that a version of this suggestion, which is the exact opposite of the assumption of many theories of attention, has been shown (Revusky, 1971) to have quite wide explanatory powers.

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