The role of contextual stimuli in the blocking paradigm

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Two experiments used rats in a conditioned lick-suppression paradigm to investigate the role of contextual stimuli in a traditional blocking paradigm. Experiment 1 demonstrated that the blocking effect could be significantly attenuated by changing contexts between the simple and compound stimulus conditioning phases of the blocking procedure. Experiment 2 demonstrated that the blocking effect could also be attenuated when both phases occurred in the same context as long as substantial context-alone exposure (i.e., extinction) was given between the two training phases. Experiment 2 also showed that the attenuating effects produced by extinguishing the training context could be alleviated if additional footshocks were given in either the training or a novel context, suggesting that context extinction may result in both a weakening of direct context-unconditioned stimulus (US) associations and a degradation of the US memory representation. These findings indicate that contextual associations can play an important role in producing the blocking effect. The potential use of contextual manipulations to distinguish between explanations for blocking deficits shown by animals with hippocampal lesions is discussed.

It is well known that prior conditioning to one element of a reinforced compound conditioned stimulus (CS) often reduces conditioning to the other element in the compound (Kamin, 1968, 1969). This phenomenon, known as "blocking," has had important implications for contemporary theories of conditioning. It suggests, for example, that the contiguous occurrence of an effective CS and unconditioned stimulus (US) does not necessarily ensure that the CS will become conditioned. On the contrary, conditioning to a given CS often depends on the degree to which other stimuli in the situation already serve as reliable signals for US occurrence.

More recently, the blocking phenomenon has also become important in evaluating the function of certain brain structures, such as the hippocampus. It has been shown, for example, that both rats and rabbits with hippocampal lesions often exhibit substantial attenuations of blocking as compared with sham animals (e.g., Rickert, Bennett, Lane, & French, 1978; Solomon, 1977). Thus, current theories of hippocampal function have had to account for why blocking deficits sometimes occur in lesioned organisms (see Schmajuk, 1984).

Since the blocking effect has implications for both behavioral and psychobiological theories, it has become increasingly important that we understand the mechanisms underlying the effect, as well as the conditions that control its occurrence. To date, most attempts to explain the blocking phenomenon have fallen into two general categories. One type of explanation is that a US loses its ability to promote conditioning as that US becomes better predicted by the stimuli preceding it (Rescorla & Wagner,

1972). Thus, if a US is already fully predicted by stimuli in the environment, new stimuli that occur contiguously with the US will fail to become conditioned. According to this view, the first phase of the blocking paradigm establishes a given CS (CS1) as a reliable signal for US occurrence. In the second phase of training, when CS1 is placed in compound with a novel CS (CS2) and the compound is reinforced, no conditioning occurs to CS2 because the US is already predictable on the basis of the occurrence of CS1.

A second, related type of explanation is that any CS that is paired with a fully predicted US decreases in salience and subsequently loses the capacity for entering into an association with that US (see Mackintosh, 1975; Moore & Stickney, 1980; Pearce & Hall, 1980). Thus, according to this view, the first phase of the blocking procedure establishes CS1 as a reliable signal for the US. In the second phase, the presence of CS1 assures that the novel CS2 will be paired with a fully predicted US. As a result, CS2 loses salience and, on subsequent trials, becomes less capable of entering into an association with the US.

It is clear that these two views make different predictions concerning the blocking effect in some cases (e.g., Dickinson, Nicholas, & Mackintosh, 1983). However, these hypotheses do share one important assumption. According to both of these positions, the degree to which blocking is obtained should ultimately depend on how surprising the US occurrence is in the compound conditioning phase of the blocking procedure. Both of these views predict that blocking should occur only when stimuli present in the second phase of training have already become reliable signals for US occurrence.

Given the presumed importance of US predictability in producing the blocking effect, it is somewhat surprising

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that experimenters have virtually ignored the role of background or contextual stimuli in the blocking paradigm. It is well known, for example, that contextual stimuli are capable of entering into associations with a US in a conditioning situation (e.g., Balaz, Capra, Hartl, & Miller, 1981; Bouton & King, 1983; Marlin, 1982). Thus, it is reasonable to assume that in the initial conditioning phase of a blocking experiment, both CS1 and contextual stimuli have the potential for becoming associated with the US. This means that in the compound conditioning phase of such an experiment, one might expect that both CS1 and contextual stimuli would contribute to the predictability of the US. In effect, contextual stimuli should, in many cases, help to make the US less surprising in the second phase of the blocking procedure.

Aside from the possibility that contextual stimuli might, themselves, become predictors for the US occurrence, there is at least one other reason to expect that such stimuli might influence the blocking effect. Several theorists have suggested that contextual stimuli can serve as retrieval cues for the memory of a CS-US association (e.g., Hirsh, 1974; Konorski, 1967; Medin, 1975; Nadel & Willner, 1980; Spear, 1973). According to this view, when an organism forms a CS-US association in the presence of specific contextual stimuli, these stimuli somehow become linked to the memory of that association. Later, if the organism is reexposed to the training context and the CS is presented, the contextual stimuli aid in retrieval of the CS-US memory and a conditioned response occurs. Conditioned responding is diminished if the CS occurs outside the training context, since retrieval of the CS-US association is relatively ineffective.

From this view, one would also predict that the occurrence of blocking should depend on the contextual stimuli present during compound conditioning. If the same contextual stimuli are present during both phases of the blocking procedure, the memory of the association established in the simple conditioning phase should be retrieved during the compound conditioning phase. Under these conditions, blocking should occur, since an organism would remember that CS1 was already a reliable predictor for the US. A change in context between the two phases of training should reduce blocking, because the memory of simple conditioning should be more difficult to retrieve.

Given these kinds of predictions, the present experiments were designed to assess the role of contextual stimuli in a traditional blocking paradigm. In the first of these experiments, we looked at the effect of changing contexts between the simple and compound conditioning phases. The second experiment was concerned with how blocking is influenced by extinguishing contextual associations between the two phases of the blocking procedure when both phases are conducted in the same context. On the basis of contemporary views of how contextual stimuli function, the expectation would be that both of these manipulations should serve to reduce the blocking effect usually obtained.

EXPERIMENT 1

The purpose of the first experiment was to assess whether or not a contextual shift between the simple and compound conditioning phases would attenuate blocking. To make this determination, all animals were exposed to a series of tone-shock pairings and later were presented with pairings of a compound tone-light CS with shock. For some animals, both simple and compound CS trials occurred in the same context. For other animals, these two training phases occurred in different contexts. Our assumption was that the former animals would show relatively poor conditioning to the light CS added during compound training. In other words, these animals should exhibit evidence of blocking. The question of interest in this study was whether or not blocking would be diminished in the animals that experienced a context change.

Method

Subjects. The subjects were 30 male albino rats derived from the Sprague-Dawley strain, bred and reared at the University of New Mexico. They were housed in individual cages and maintained under a 12:12 light:dark cycle. At the beginning of the experiment, all animals were between 90 and 120 days of age, and their body weights ranged from 240 to 300 g. All behavioral testing was conducted during the light phase of the light:dark cycle.

Apparatus. Two identical lick chambers, adapted from operant chambers and manufactured by Lafayette Instrument Co. (Model 8000), were employed. Each chamber measured 27×21×26 cm and was composed of two aluminum and two Plexiglas walls with a Plexiglas lid. The floor of each chamber consisted of 0.6-cm-diameter stainless steel rods, spaced 1.7 cm apart. The rods were connected with electrical wire outside the walls of the chamber. An aperture measuring 2.4 cm in diameter was located 12.0 cm from the floor and centered in one aluminum wall to accommodate a drinking tube. A drinkometer (Lafayette Instruments, Model A121) was placed into a circuit that remained open except when an animal stood on the chamber floor and contacted the drinking tube. Each such contact resulted in a pulse to a counter that recorded the number of tube contacts.

Conditioning trials were presented in a large Plexiglas chamber measuring 36×36×69 cm. The floor of this chamber was identical to that described for the lick chambers. A 1.5-mA scrambled grid shock would be delivered to the floor by means of a Grason-Stadler shock generator (Model E1064GS). Two CSs were employed. The first was a 200-Hz, 90-dB tone that was delivered through a speaker mounted at the top of the chamber. The second CS was a 15-W flashing light, also located at the top of the chamber.

Two experimental rooms (A and B) were employed for this study. These rooms differed distinctively in terms of odor, size, and lighting. To further differentiate between contexts, the walls of the conditioning chamber were clear Plexiglas when located in Room A and striped when located in Room B. In Room B, striped poster-board panels, consisting of alternating 1-in. black and white strips, were hung on the outside of the clear Plexiglas walls. The specific characteristics of the rooms are listed in Table 1.

Procedure. Four days prior to any experimental treatment, all animals were placed on a 23.75-h water-deprivation schedule. On each of these days all animals were handled for 5 min and then were given 15-min access to water in their individual home cages. After these pretraining days, all animals were exposed to the lick chambers in Room A. On Day 1 each animal was placed in a chamber for 30 min with the lick tube protruding 1 cm into the chamber wall.

Table 1
Characteristics of Experimental Treatment Rooms

	Room	
	A	B
Dimensions	16.0 × 11.0 ft	7.5 × 5.0 ft
Lighting	Dim: 0.17 fL	Bright: 1.0 fL
Odor (room deodorizer)	None	Lemon
Noise Level	None: 45–50 dB	Fan: 63–65 dB
Gloves	Smooth	Rough
Holding Cage	Wooden	Wire mesh
Conditioning Chamber Walls	Clear Plexiglas	Striped

Since the purpose of this day was to familiarize the animals with the lick chambers and to initiate drinking from the tube, lick latencies were not recorded. On Days 2 and 3, the lick tube was flush with the wall and latencies (in seconds) to begin licking and latencies to complete the first 40 and second 40 licks were recorded as an index of adaptation to the apparatus. Since there were no appreciable differences between subjects in adaptation to the enclosure by Day 3, the animals were assigned randomly to one of three groups consisting of 10 animals each.

The simple conditioning phase was conducted on Days 4 and 5 in the Plexiglas conditioning chamber located in either Room A or Room B. The standard blocking group (Same) received four pairings per day of a 10-sec tone with a 2-sec footshock in Room A. Pairings occurred at 5, 13, 22, and 28 min during a 30-min session on each day, with tone offset being concurrent with shock onset. Animals in the context shift blocking group (Different) received exactly the same treatment with the exception that conditioning occurred in Room B instead of Room A. Animals in the third, control group (Control) remained in their home cages on these 2 conditioning days.

Animals in Groups Same and Different received no explicit treatment on Days 6 and 7, but instead were taken to Room A, where they remained in their home cages for 30 sec and then returned to the animal colony. Animals in Group Control continued to remain in their home cages. These days were included to allow for comparisons between this experiment and the subsequent study, in which subjects would receive extinction treatments and additional US presentations between the two training phases of the blocking procedure.

The compound conditioning phase took place on Days 8 and 9 and, for all animals, was conducted in Room A. Conditioning consisted of four pairings of a 10-sec tone–flashing-light compound stimulus followed immediately by the same footshock as was employed in the simple training phase. Also, as in the simple conditioning phase, pairings occurred at 5, 13, 22, and 28 min during a 30-min session on each day with tone–light offset being concurrent with shock onset.

During both the simple and compound conditioning sessions, animals receiving treatments were taken to the appropriate room, one at a time, and placed in a holding cage specific to the particular context (see Table 1) for 30 sec prior to being placed in the conditioning chamber. Additionally, all animals received 15-min access to water in their home cages daily. Water was provided after treatment on conditioning days.

On Day 10, all animals were returned to Room A, placed in the lick chambers, and given a 30-min lick-recovery session. Latencies to begin licking and latencies to complete Licks 0–40 and 40–80 were again recorded to assess any generalization of fear between the lick chamber and the conditioning apparatus, and to ensure that all animals were restored to their baseline licking rates as measured on Day 3.

Testing for conditioned suppression to the blocked stimulus (i.e., the flashing light) was conducted on Day 11. Testing consisted of taking each animal individually into Room A, giving it a 30-sec

confinement period in the wooden holding cage, and then placing it into a lick chamber for testing. Upon emission of Lick 40, the flashing light was presented and remained on until the subject either completed the next 40 licks or suppressed licking for 1,800 sec. This preparation, which has been employed by Miller and his colleagues (e.g., Balaz, Gutsin, Cacheiro, & Miller, 1982; Schachtman, Gee, Kaspro, & Miller, 1983), ensures that all subjects are licking when the nonreinforced testing stimulus is presented. Latencies to complete the first and second 40 licks were recorded, with the critical dependent variable being the latency to complete the second 40 licks in the presence of the light. This same testing procedure was then employed on Day 12 to assess conditioned suppression in the presence of the blocking stimulus (i.e., the tone).

Results and Discussion

Two animals were discarded due to equipment malfunctions. Both were replaced with similar animals. On both the lick recovery day and the 2 test days, all animals were required to begin licking within 10 min after being placed in the operant chambers. All animals in the present study met these requirements. Latencies to begin licking and to complete the first and second 40 licks on Day 3 (the last day of lick training), Day 10 (the lick recovery day), and the 2 test days were transformed to log latencies (base 10) to permit the use of parametric statistics. A rejection region of .05 was employed for all statistical analyses. An analysis of variance performed on the Day 3 and Day 10 latency data revealed no significant differences between groups to begin licking or to complete the first and second 40 licks (all p s > .05). Separate analyses further showed that the groups did not differ in terms of the total number of licks emitted on these 2 days (all p s > .05). Taken together, these data indicate that lick rates were relatively equivalent across the treatment groups prior to the testing sessions.

On the initial test day (Day 11), the groups did not differ in terms of their latencies to initiate licking or in terms of their latencies to complete the first 40 licks (p > .05 in both cases). The mean log latencies to complete Licks 40–80 in the presence of the flashing light are shown in Figure 1. An analysis of these data revealed a significant effect of treatment [$F(2,27) = 8.38$, $p < .05$]. The Newman-Keuls multiple comparison statistic (Kirk, 1968) was employed to analyze differences among the individual group means. On the basis of this test, it was found that Group Same manifested significantly shorter latencies in the presence of the flashing light than did either of the other two groups. Groups Control and Different did not differ from each other in terms of this measure. Thus, Group Same exhibited significantly less lick suppression in the presence of the light than did the other two groups.

On the 2nd test day (Day 12), again the groups did not differ in their latencies to begin licking or to complete the first 40 licks (p > .05 in both cases). The mean log latencies to complete the last 40 licks in the presence of the tone are shown in Figure 1. This figure suggests that all groups exhibited relatively long latencies in the presence of the tone. Furthermore, an analysis of variance revealed that the groups did not differ in terms of this measure (p > .05).

Figure 1. Mean test-trial log latencies (base 10) to complete 40 licks in the presence of the flashing light (L) on Day 11 and tone (T) on Day 12 (Experiment 1).

The results of this study reveal that the typical blocking effect can be obtained with the present parameters. This effect is represented by the difference between the Control and Same groups when they were tested with the flashing light. These groups each received eight total pairings of the tone-light compound with shock in Phase 2 of training. However, animals in the Same groups had previously received eight pairings of the tone CS with shock. As a result, the animals in the Same condition show much less evidence of conditioning to the light CS following the compound conditioning phase.

Importantly, these results also show that the blocking effect is attenuated significantly by a change in context between single stimulus and compound stimulus training. Animals exposed to a shift in context (Group Different) failed to exhibit evidence of blocking. These rats suppressed licking in the presence of the light to almost the same degree as the Control animals. This finding is consistent with the idea that the contextual stimuli present during compound training help to determine whether or not the US will be surprising. Apparently, when novel contextual stimuli are present in the compound conditioning phase, the surprisingness of the US is enhanced even though a previously conditioned CS (the tone) precedes each occurrence of the US. As a result, blocking of the novel CS (the light) fails to occur.

Finally, the lick-suppression data from the 2nd test day suggest that the groups exhibited equivalent conditioning to the tone CS. These data are only suggestive, since suppression to the tone may have been influenced by the prior test with the light CS. Still, these data indicate that by the end of compound training, all groups had become conditioned to the tone to an equal degree, whereas conditioning to the light depended on the specific treatment conditions.

EXPERIMENT 2

The results of Experiment 1 indicate that contextual stimuli can play an important role in the production of the blocking effect. The purpose of the second study was to determine the degree to which this contextual influence is mediated by direct context-US associations formed during the simple training phase of the blocking procedure. We reasoned that if context-US associations contribute to the blocking effect, then the extinction of these associations following the simple training phase should significantly reduce blocking of the novel CS during the compound conditioning phase. To test this prediction, all rats in Experiment 2 received both single stimulus and compound stimulus training in the same context. However, some animals were given nonreinforced exposures to the

context between the single and compound stimulus conditioning phases. The major question addressed in this study was whether or not extinction of contextual associations would reduce the blocking effect.

Although context-alone exposures following the simple conditioning phase should serve to reduce direct context-US associations (e.g., Marlin, 1982), the effects of such an extinction manipulation are not always interpretable on that basis alone. Some investigators have demonstrated that extinction trials not only reduce associations, but may also serve to degrade an organism's memory representation of the US (e.g., Rescorla & Heth, 1975). Thus, decreases in performance following extinction often result from the combined effects of a reduced association and a degraded US memory.

To determine the mechanism for any extinction effects in the present study, two important control conditions were used in this experiment. In one of these conditions, rats were exposed to shock-alone presentations in the previously extinguished context prior to the compound conditioning phase. We reasoned that this manipulation should serve to reestablish any context-US associations that had been extinguished and should also reinstate an animal's memory of the US. In the other of these conditions, rats were given shock-alone presentations in a novel context after extinction of the training context. Such a manipulation should reinstate an organism's US representation, but should not reestablish any associations between the training context and the US. By comparing the performance of animals in these conditions, it should be possible to determine the basis for any extinction effects found in the present study.

Method

Subjects and Apparatus. Eighty male rats, similar to those employed in the previous experiment, served as subjects. The conditioning apparatus, lick chambers, conditioning contexts, and stimulus parameters were the same as those utilized in Experiment 1.

Procedure. Pretraining and lick-training procedures were carried out precisely as in Experiment 1. As in the previous study, there were no appreciable differences between subjects in adaptation to the lick chambers by Day 3, and animals were assigned randomly to one of five groups consisting of 16 animals each.

On Days 4 and 5, animals in four of the treatment conditions [Groups EXTN(A), EXTN(A)/EXP(A), EXTN(A)/EXP(B), and Blocking] underwent the simple conditioning phase of the blocking procedure. On each of these days, these rats were placed in the conditioning chamber in Room A for 30 min. During this time, they received four tone-shock pairings distributed over the session, as in Experiment 1. Animals in the remaining group (Control) remained in their home cages on these 2 conditioning days.

On Day 6, animals in Groups EXTN(A), EXTN(A)/EXP(A), and EXTN(A)/EXP(B), received two 30-min exposures to the conditioning chamber, still located in Room A. These exposure sessions simply involved placing each animal in the conditioning chamber without any presentations of the tone or shock. The two exposure sessions were separated by approximately 3 h in the case of each animal. Rats in the standard, Blocking group received no exposure sessions on this day. Instead, these animals were simply taken to Room A, where they remained in their home cages for 30 sec be-

fore being returned to the animal colony. Animals in Group Control again remained in their home cages on Day 6.

Day 7 involved giving additional shock exposures to rats in Groups EXTN(A)/EXP(A) and EXTN(A)/EXP(B). Rats in Group EXTN(A)/EXP(A) received two footshocks in the conditioning chamber located in Room A. These footshocks were identical to those used during conditioning, and they occurred at 5 and 21 min during a 30-min session. These shock presentations occurred in the absence of any nominal CS. Rats in Group EXTN(A)/EXP(B) received exactly the same treatment, except that the shock presentations occurred in Room B rather than in Room A. On this day, animals in Groups Blocking and EXTN(A) were simply given a 30-sec exposure to Room A in their home cages; rats in Group Control remained in the animal colony.

The compound conditioning phase of this experiment took place on Days 8 and 9 in Room A. Animals in all groups received four pairings of the compound CS (tone and flashing light) with shock. These pairings were distributed over a 30-min session in the conditioning chamber. Subsequent lick recovery (Day 10) and testing (Days 11 and 12) procedures were identical to those employed in Experiment 1.

Results and Discussion

Two animals were discarded due to equipment malfunctions, 3 were eliminated because of illness, and 2 failed to begin licking within the required 10 min on the lick-recovery day. All 7 of these animals were replaced with animals that had similar characteristics.

The lick-latency scores for all animals were converted to log latencies, and the appropriate analyses were performed. As in the first experiment, there were no differences between groups to begin licking or to complete the first and second 40 licks on the last day of lick training (Day 3) or lick recovery (Day 10) (all p s > .05); nor did the total number of licks emitted on these 2 days differ between groups (all p s > .05). Furthermore, no significant differences between groups were detected in latencies to begin licking or to complete the first 40 licks on either test day (all p s > .05).

Mean log latencies to emit Licks 40–80 on Day 11 in the presence of the flashing light and on Day 12 in the presence of the tone are illustrated in Figure 2. The analysis of variance performed on the Day 11 latency measures revealed a significant effect of treatment [$F(4,75) = 8.07, p < .05$]. As would be expected, the Newman-Keuls statistic indicated that Group Blocking exhibited significantly shorter latencies in the presence of the light than did Group Control. Of greater importance is the finding that the animals that received two context-alone exposures [i.e., Group EXTN(A)] displayed significantly longer latencies than did Group Blocking. This finding suggests that when context-alone exposures follow the simple conditioning phase, the typical blocking effect is attenuated.

Regarding the remaining two groups, the results obtained are somewhat more ambiguous. As evidenced by the Newman-Keuls statistic, Groups EXTN(A)/EXP(A) and EXTN(A)/EXP(B) did not differ from one another and neither differed from Group Blocking. That is, both groups displayed blocking regardless of where their US

Figure 2. Mean test-trial log latencies (base 10) to complete 40 licks in the presence of the flashing light (L) on Day 11 and tone (T) on Day 12 (Experiment 2).

exposures were given after extinction. This effect was further confirmed by the finding that both of these groups manifested significantly shorter latencies than did Group Control. The only comparison that tends to differentiate these groups is that with Group EXTN(A). The group given shock exposures in the training context [EXTN(A)/EXP(A)] did exhibit significantly shorter latencies than did Group EXTN(A). However, the group given shock exposures in the novel context [EXTN(A)/EXP(B)] did not differ from Group EXTN(A) in terms of this measure.

These findings suggest that shock exposures in the previously extinguished context were somewhat more effective in restoring the blocking effect than were shock exposures in the novel context. However, both types of shock exposure tended to alleviate the effects of extinguishing the training context. Thus, it appears that in the present case, context extinction reduced the blocking effect both by reducing context-US associations and by degrading the animals' US memory representation. If extinction had served only to reduce context-US associations, then shock exposures in a novel context should have done little to restore the blocking effect.

Finally, it is notable that all groups exhibited relatively long latencies in the presence of the tone. Furthermore, an analysis of variance performed on these latencies revealed no significant differences as a function of treat-

ment conditions. This indicates that although the treatment conditions produced differential responding in the presence of the light, these manipulations had little effect on the degree of conditioning to the tone CS.

GENERAL DISCUSSION

The question addressed in these experiments was whether contextual stimuli could contribute to the occurrence of the blocking effect. The results of these studies clearly provide an affirmative answer to this question. In Experiment 1, we found that the blocking effect could be virtually eliminated by changing contexts between the single and compound stimulus training phases of the blocking procedure. In Experiment 2, we found that the blocking effect could also be attenuated by extinguishing the single stimulus training context prior to the compound conditioning phase.

Although these findings indicate that contextual stimuli can play an important role in the production of blocking, they do not provide a clear indication of the mechanism underlying this contextual influence. As we have previously noted, contemporary views of contextual effects provide at least two suggestions as to how contextual stimuli might aid in the production of blocking. According to one view, contextual stimuli should become associated with

the US during the initial stage of the blocking procedure (e.g., Rescorla & Wagner, 1972). Thus, the presence of these same contextual stimuli in the compound conditioning phase should enhance the predictability of the US and should, in turn, reduce conditioning to the novel CS. According to another view (e.g., Hirsch, 1974; Nadel & Willner, 1980; Spear, 1973), the contextual stimuli present during the initial simple training phase of the blocking procedure should become effective retrieval cues for the CS-US association formed during that stage. Thus, the presence of these contextual cues during the compound phase of the procedure should enhance blocking by facilitating retrieval of the previously formed association. In effect, the presence of these stimuli should enhance the effectiveness of the previously conditioned CS as a blocking agent.

Clearly, the results of Experiment 1 are consistent with both of these views, since both views would predict a reduction in blocking when novel contextual stimuli are present in the compound conditioning phase. On the other hand, the results of Experiment 2 would seem at first glance to be more in accord with the idea that context-US associations are instrumental in the production of blocking. This is because this view predicts that extinction of contextual associations formed during the simple training phase should attenuate blocking in the compound training phase. However, although Experiment 2 did demonstrate that exposure to the simple training context does reduce blocking, the specific mechanism for this effect was unclear. These results indicated that the contextual exposure may have resulted in a degradation of the US representation as well as a weakening of context-US associations. Thus, the degree to which context-US associations are necessary for the production of blocking remains unclear. Further work will be necessary to delineate the basis for this contextual control over the blocking effect.

Although the present studies demonstrate that contextual stimuli can influence the occurrence of blocking, these findings do not imply that such contextual control will occur under all circumstances. On the contrary, pilot work currently underway in our laboratory suggests that the contextual control of blocking may depend on factors such as the number of conditioning trials that occur in the simple conditioning phase. This preliminary work indicates that context changes diminish blocking to a much lesser degree when the simple conditioning phase involves numerous tone-shock pairings that are widely distributed in time. Should these preliminary findings be confirmed, it may become possible to use manipulations of context to distinguish between explanations for the blocking deficits shown by animals with hippocampal lesions.

To illustrate this point, consider the explanation of blocking deficits proposed by Moore and Stickney (1980) as opposed to the interpretation offered by Hirsch (1974). According to Moore and Stickney, blocking normally occurs because animals tend to "tune out" redundant stimuli in a conditioning situation. In other words, in Stage 2 of the blocking procedure, animals are confronted with a CS

that is already a reliable signal for the US. This means that the novel CS that is added during this stage is viewed as a redundant signal for the US and is progressively tuned out or ignored. For this reason, little conditioning occurs to the novel CS. According to this view, animals with hippocampal lesions are less adept at tuning out redundant stimuli, and thus show greater conditioning to the novel CS than do sham subjects.

Within this theoretical framework, contextual stimuli can contribute to the blocking effect by becoming reliable signals for US occurrence during the initial conditioning phase. However, blocking can also occur in situations in which contextual stimuli are relatively ineffective as long as the CS from the initial conditioning phase becomes a reliable signal. In effect, this hypothesis predicts that animals with hippocampal lesions should always exhibit deficits in blocking, regardless of whether or not contextual stimuli contribute to the blocking effect.

Alternatively, Hirsch (1974) accounts for blocking deficits by proposing that lesioned animals are deficient in their ability to use contextual stimuli as memory retrieval aids. Hirsch's view suggests that in Stage 2 of the blocking procedure, sham animals utilize the context to retrieve the memory of the CS-US association formed in Stage 1. Associations to the novel CS are blocked because an animal remembers that the original CS has already become a reliable signal for US occurrence. Animals with hippocampal lesions are presumed to exhibit blocking deficits because they are unable to use the context in Stage 2 to help them to remember the CU-US association formed in Stage 1.

One implication of this view is that lesioned animals should show blocking deficits only under conditions in which contextual stimuli contribute to the blocking effect. If blocking occurs in the absence of contextual control, then there is little reason to predict that lesioned animals would perform differently than shams. In other words, if under some circumstances, blocking does not depend on the presence of Stage 1 contextual stimuli, lesioned animals should show minimal deficits in blocking, since these deficits are presumed to result from an inability to utilize contextual cues.

Clearly, such an analysis depends on identifying situations in which blocking is *not* influenced by the training context, as well as situations in which contextual control is strong. By understanding the role context plays in this paradigm, it may be possible to accomplish more than simply increase our understanding of the blocking phenomenon. It may also be possible to use contextual manipulations to clarify the role of the hippocampus in conditioning situations.

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