

Negative Priming in Associative Learning: Evidence From a Serial-Conditioning Procedure

R. C. Honey, Geoffrey Hall, and Charlotte Bonardi

Three experiments investigated the suggestion that a predicted or primed stimulus commands less processing and consequently elicits a weaker conditioned response (CR) than a stimulus that is not primed. In each experiment rats received initial training in which the presentation of each of 2 serial compounds, A-X and B-Y, was followed by the delivery of food. Subsequently, X's capacity to elicit the CR, approaching the site of food delivery, was assessed when X was preceded by Stimulus A (i.e., primed) or was presented after Stimulus B. Stimulus X elicited a more vigorous response when it was presented after B than when it followed A. These results show that the ability of one event to elicit its CR is reduced if its presentation has been predicted by some other event. This *negative priming* effect supports one aspect of Wagner's (1981) model of Pavlovian conditioning.

Wagner (1976) argued that a number of seemingly diverse phenomena in habituation and conditioning might reflect the operation of a relatively small set of information-processing principles. Much of the explanatory burden of Wagner's thesis was borne by the principle that in order for a stimulus to be processed in an effective way its presentation should be unexpected or surprising. This suggestion continues to represent an important part of his more recent, formal analysis of Pavlovian conditioning (e.g., Wagner, 1981). The way in which the suggestion is currently embodied can be illustrated by considering the situation in which a subject experiences presentations of a tone that are signaled by a light.

It is assumed that initially the presentations of the light and the tone will be surprising and each will provoke a primary state of activation (A1) in its corresponding central representation or node. Nodes that are concurrently activated in this way will, it is assumed, become linked so that on subsequent occasions, presentation of the light will be able to activate the representation of the tone. The resulting associatively activated, *primed*, state is held to have different properties from the state produced by presentation of the tone itself. In particular, Wagner (1981) suggested that associative priming is capable of generating only a secondary state of activity (A2) in a node. For as long as the node remains in A2, presentation of the corresponding stimulus will be incapable of generating the A1 state. Furthermore, because it is necessary for a stimulus to generate the A1

state to receive access to limited processing resources, the presentation of the light will result in the tone being poorly processed when it arrives. We refer to cases in which predicting an event appears to reduce the effectiveness of the processing it receives as *negative priming* (without necessarily implying a direct parallel with phenomena in human information processing that have received this label; see, e.g., Allport, Tipper, & Chmiel, 1985).

A failure to receive full processing will show itself in a number of ways; a primed stimulus will, for instance, have difficulty in entering into new associations and will be less effective than an unexpected stimulus at evoking responding. Although rival explanations of the phenomena are available, support for these proposals has been derived from the blocking effect (e.g., Kamin, 1969) and from the effect known as conditioned diminution of the unconditioned response (UR)—the observation that the magnitude of the UR evoked by a given unconditioned stimulus (US) diminishes over the course of conditioning in which a conditioned stimulus (CS) reliably precedes the US (e.g., Kimmel & Pennypacker, 1962). These phenomena have both been taken to indicate that a predicted stimulus is less able than an unexpected stimulus to function as a US. The former phenomenon is thought to show the inability of a predicted US to enter into further associations; the latter is taken to reflect the fact that the CS, by virtue of its association with the US, becomes able to establish the A2 state in the US node and thus interfere with the processing necessary for elicitation of the UR.

Evidence that a primed stimulus is less able than an unexpected stimulus to function as a CS has been sought in studies of the role of context. It is well established that nonreinforced preexposure to a stimulus reduces the rate at which that stimulus will become an effective signal for a US and that this latent-inhibition effect can be reduced or even abolished if preexposure and conditioning take place in different contexts (e.g., Channell & Hall, 1983; Hall & Honey, 1989; Lovibond, Preston, & Mackintosh, 1984). The priming interpretation of these findings is that during preexposure an association develops between the context and

R. C. Honey, Sub-Department of Animal Behaviour, University of Cambridge, Cambridge, England; Geoffrey Hall and Charlotte Bonardi, Department of Psychology, University of York, York, England.

This research was supported by a grant from the United Kingdom Medical Research Council. We thank Elizabeth Ray and Alan Willis for their assistance.

Correspondence concerning this article should be addressed to R. C. Honey, Sub-Department of Animal Behaviour, University of Cambridge, Madingley, Cambridge CB3 8AA England, or Geoffrey Hall, Department of Psychology, University of York, Heslington, York YO1 5DD England.

the CS; this will mean that the CS is represented in the A2 state when it is presented in the preexposure context but not when it occurs elsewhere. Consequently, a preexposed CS will be poorly processed and poor at forming new associations unless there is some change in context between preexposure and conditioning.

Evidence that a primed CS is less able to evoke its conditioned response (CR) has been harder to come by. An implication of the priming account is that presenting a trained CS in a context different from that used for initial conditioning should, other things being equal, produce an enhancement in the magnitude of the CR because the CS will be surprising and receive full processing. However, the many studies of the context specificity of conditioned responding (for reviews, see Bouton, 1990; Hall, 1991), have, with very few exceptions (see Kaye & Mackintosh, 1990), found no increase in the vigor of the CR, and in many cases the change of context resulted in a loss of responding. These results, then, are not encouraging for the priming theory. It seems possible, however, that a variety of processes will be engaged when a CS is presented in a new context, and one or more of these processes might act to obscure any effect of priming. This possibility is taken up in detail in the General Discussion, where we further argue that the conditions of training in experiments on the context specificity of conditioning tend not to be optimal for producing a priming effect. Accordingly, it seemed worthwhile to attempt to devise a different procedure that would maximize the chances of seeing a more vigorous CR to an unexpected than to a primed CS.

In each of the three experiments reported, we used variants of the same basic design. Rats received initial training in which the CS of interest was itself reliably preceded by some other stimulus. This other stimulus should, according to the theory advanced earlier, form an association with the target CS, become able to prime the representation of that CS, and thus restrict the ability of the CS to evoke its CR. In the test phase, the target was presented without the prime (the target was preceded, instead, by some other event with which it had not previously been associated), and any change in the magnitude of the CR was monitored.

Experiment 1

In this experiment, we used an appetitive-conditioning procedure with rats as the subjects. Its design is summarized in Table 1. During training, each rat received presentations of two serial compounds, A-X and B-Y, that were paired

Table 1
Design of Experiment 1

Training	Testing
A-X - +	A-X & B-X
B-Y - +	B-Y & A-Y

Note. Each subject received food-reinforced (+) serial conditioning trials with two serial compounds, A-X and B-Y. Subsequently, the level of responding to X and Y was measured as a function of whether they had been preceded by A or by B.

with the delivery of a food pellet. On the basis of previous research (e.g., Channell & Hall, 1983), it was expected that subjects would come to approach the food tray during X and Y—a tendency that might also be apparent during A and B. This serial-conditioning design was used because it should foster the development of potent A-X and B-Y associations. These associations, according to Wagner (1981), should impede the processing of X and Y, respectively, and reduce the CR that they elicit. This possibility was investigated in a subsequent test by comparing the level of responding elicited by, for example, X when it was preceded by A with the level X elicited when its presentation was preceded by B. Negative priming would be evident if X elicited a less vigorous CR when its presentation had been signaled by A than when it had been preceded by B.

This experimental design allows the possibility that the Priming Stimuli A and B might themselves acquire associative strength (and hence elicit CRs), either because X and Y become secondary reinforcers or as a result of direct associations between A and B and the delayed US. This does not complicate interpretation of the results, however, because the associative strengths of A and B will be equated, and thus any differences in their ability to modify responding to a target CS could not be a consequence of their own tendencies to elicit conditioned responding.

Method

Subjects

The experiment was conducted in two replications. In the first study, the subjects were 8 naive male hooded Lister rats that had a mean ad lib weight of 379 g (range = 335–425 g). In the second study, the subjects were 8 naive male hooded Lister rats with a mean ad lib weight of 478 g (range = 410–555 g). The rats were maintained at 80% of their free-feeding weights.

Apparatus

Four Skinner boxes, supplied by Campden Instruments Limited, were used. Each box contained a recessed food tray to which 45-mg food pellets could be delivered. The opening to the food tray was guarded by a transparent rectangular plastic flap (6 cm high and 5 cm wide) that was hinged along its top edge to the top of the entrance to the food tray. Pushing the flap inward from its vertical resting position allowed access to the food tray. These movements actuated a microswitch, and each closing of the switch was recorded as a response. The flap returned to its resting position as rats removed their snouts or paws from the tray. Four stimuli were used: a jewel light that was mounted adjacent to, and to the right of, the food tray; a light that was mounted inside the food tray; and a 2-KHz tone and a white noise presented from a speaker mounted above the aluminum ceiling at an intensity of 82 dB(A), re 20 $\mu\text{N}/\text{m}^2$. The boxes were dimly lit by a jewel light that was positioned on the wall above the food tray. The background noise level of 65 dB(A), re 20 $\mu\text{N}/\text{m}^2$, was produced by a ventilation fan.

Procedure

Pretraining. On the first day of the study the subjects were trained to collect 45-mg food pellets from the food tray during

two 40-min sessions. The pellets were delivered on a variable time (VT) 60-s schedule.

Training. The subjects then received appetitive-conditioning trials with the two serial compounds, A-X and B-Y. The elements of each compound were 30 s in duration, and the offset of the first element coincided with the onset of the second. Illumination of the right jewel light and of the food tray light served as the first elements, A and B, and white noise and a tone were used as the second elements, X and Y. The identity of the visual stimulus that served as A or B and that of the auditory stimulus that acted as X or Y were counterbalanced. There were two A-X trials and two B-Y trials in each session. A single food pellet was delivered after each serial compound. The first trial occurred 440 s after the start of each session, and the intertrial interval was 500 s. The order in which the trials were presented within a session was random. There were two 40-min training sessions each day for 4 days.

Testing. In the first study, subjects received a single 40-min test session that contained four nonreinforced trials. On two of these trials (S, or same, trials), subjects were presented with the compounds that had been presented during training. On the remaining trials, the different (D) trials, subjects received one presentation of A-Y and one of B-X. The order in which these trials was presented was counterbalanced, with half of the subjects receiving the sequence SDDS and the remainder receiving the sequence DSSD. Half the subjects received A-X as their first S trial, and half received B-Y. Similarly, half received A-Y as the first D trial, and half received B-X. Subjects in the second study were treated in an identical fashion except that they received a second test day. On this day subjects that were given the test sequence SDDS on Test 1 received the sequence DSSD, and subjects that were given the sequence DSSD on the first test day received the test sequence SDDS.

Responding was recorded separately for each element of each compound and for the 30-s period that preceded the onset of each trial. To correct for individual differences in the background rate of responding and within-session fluctuations in such responding during the test, an elevation ratio was calculated in which the rate of responding during the stimuli was divided by the rate of responding in the prestimulus period; if there was no responding during this period, the rate of responding during the stimulus-free periods in the rest of the session was used. The rejection level that was adopted for all analyses was $p < .05$.

Results

By the final session of training, the subjects were reliably approaching the food hopper during X and Y—a tendency that was somewhat less marked during the first elements of the serial compounds (A and B). The critical test results of Experiment 1 are presented in Figure 1.

The identity of the stimulus that served as A or B and as X or Y made no difference to the pattern of results that was observed. Accordingly, analyses were conducted with the scores pooled across these counterbalanced factors. There was no difference in the rate of response during the first elements of the compounds, A and B, as a function of trial type, S or D. Thus, the mean elevation ratios on S and D trials were 1.47 and 1.91, respectively. An analysis of variance (ANOVA) with trial type (S or D) and replication as factors revealed no effect of either factor and no interaction between the factors ($F_s < 1$). The critical results from Experiment 1, the responding during the second elements of

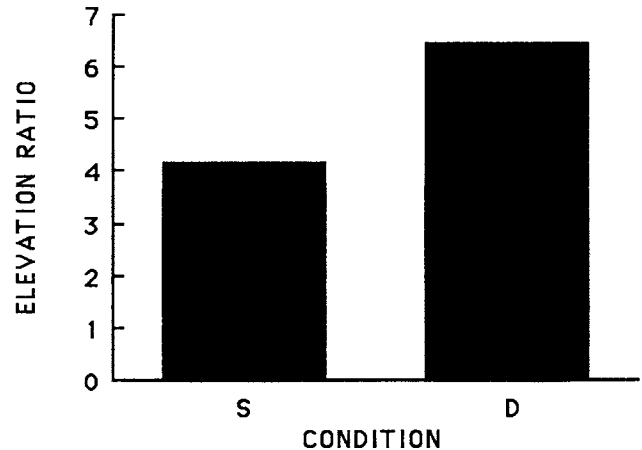


Figure 1. Experiment 1: Mean elevation ratios during the second target elements of the same (S) serial compounds (A-X and B-Y) and the different (D) serial compounds (A-Y and B-X).

the serial compounds on S and D test trials (pooled across the two replications), are depicted in Figure 1. It is clear that subjects responded at a higher rate on D than on S trials. An analysis of responding during the second elements of the compounds revealed an effect of trial type, $F(1, 14) = 4.71$, no effect of replication, and no interaction between these two factors ($F_s < 1$). The mean background rates of responding used to calculate the elevation ratios were 2.03 responses per minute (RPM; Replication 1) and 1.40 RPM (Replication 2) on S trials and 2.29 (Replication 1) and 0.97 RPM (Replication 2) on D trials. An analysis of the individual scores on which these means were based revealed no effect of stimulus type, no effect of replication, and no interaction between these factors ($F_s < 1$).

Discussion

The results of Experiment 1 were clear-cut. Rats are less likely to show conditioned responding during an auditory target stimulus when it is presented after a visual cue that had preceded it during training than when the target is preceded by some other visual stimulus.

This outcome is that predicted by the associative-priming theory (Wagner, 1981) outlined in the introduction. Most theories of associative learning (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972) allow that during training associations would develop between the first and second elements of the serial compounds, between A and X and between B and Y. However, the fact that X, for example, was more likely to elicit responding when it was presented after B than when it was presented after A is predicted only by Wagner's (e.g., 1976, 1981) theory, with its assumption that associative activation of the representation of X will make it a less effective CS.

Given the theoretical significance of the results of Experiment 1, a second study was conducted in which we attempted to establish the reliability of the results and to extend the range of conditions under which they can be found.

Experiment 2

There were two groups of subjects in Experiment 2, the S and the D groups. Both groups initially received the training experienced by the subjects in Experiment 1. That is, they were given presentations of two serial compounds, A-X and B-Y, that signaled the arrival of food. Subsequently, subjects in the S group simply received further reinforced training with the A-X and B-Y compounds. The D group, on the other hand, was given reinforced presentations of A-Y and B-X. Experiment 2, therefore, differed from Experiment 1 in two respects. First, the comparison of interest, the level of responding elicited when X, for example, was predicted by A or was unsignaled and preceded by B, was between subjects. Second, the test trials were reinforced in Experiment 2 and nonreinforced in Experiment 1. According to the interpretation of the results of Experiment 1 based on Wagner (1981), neither of these variables should influence the outcome of the study. Accordingly, responding to the target events during the test should be more vigorous in the D group than in the S group, because in the latter group, the presentation of X and Y will be predicted by A and B, respectively, whereas in the former group this will not be so.

Method

Subjects and Apparatus

The subjects were 16 naive male hooded Lister rats that had a mean ad lib weight of 379 g (range = 350–415 g). The rats were maintained at 80% of their free-feeding weights. The apparatus was that used in Experiment 1.

Procedure

The initial stages of training were identical to those of Experiment 1. Thus, in the first two sessions, subjects were trained to collect food pellets from the food tray, and in the following eight sessions, subjects received presentations of A-X and B-Y that terminated in the delivery of food. Details of the training procedure that have not been mentioned were identical to those of Experiment 1.

During the test session, subjects in the S group continued to receive reinforced training with the two serial compounds, A-X and B-Y. Subjects in the D group were treated in an identical fashion except that presentations of X were preceded by B, and presentations of Y were preceded by A. Details of the test stage that have not been mentioned were identical to those used during training.

Results and Discussion

One subject failed to respond during the final session of training and was, therefore, excluded from the study. Responding during the first elements (A and B) of the serial compounds on the final session of training was similar in the two groups. Thus, on the final session of training, the mean elevation scores were 0.47 for the S group and 0.93 for the D group. Analyses of the individual elevation scores on which these means were based confirmed that the group's scores did not differ during the final day of training ($F < 1$).

Responding during the target elements (X and Y) of the serial compounds, with mean elevation scores of 6.16 for S group and 6.25 for the D group, also did not differ ($F < 1$) during training. There was some tendency for subjects in the D group to respond at a higher rate during the stimulus-free periods (with a mean of 2.11 RPM) than subjects in the S group (with a mean of 0.90 RPM), but this difference was not statistically significant, $F(1, 13) = 3.24$.

During the test, subjects continued to respond at approximately equivalent rates during the first elements of the serial compounds. Thus, the mean elevation ratio in the S group was 0.93, and the mean elevation ratio in the D group was 0.87. Statistical analysis confirmed that these scores did not differ ($F < 1$). The critical results from Experiment 2, the level of responding during the second elements of the compound stimuli, are shown in Figure 2. Statistical analysis confirmed the impression that subjects in the D group were more likely to respond during X and Y than were subjects in the S group, $F(1, 13) = 5.24$. The mean background rate of responding during the test session was 1.51 RPM for the S group and 1.37 RPM for the D group. These scores did not differ ($F < 1$).

The results of Experiment 2 closely parallel those of Experiment 1. In both, responding during a CS was less evident when that CS was signaled by the cue that had preceded it during training than when the CS was presented after a different cue. Experiments 1 and 2 are, indeed, formally identical, differing only in that Experiment 1 used a within-subjects design and a nonreinforced test procedure and Experiment 2 used a between-subjects design and a reinforced test procedure. In Experiment 3 we return to the procedures used in Experiment 1 to investigate the source of the effect of interest in more detail.

Experiment 3

The results of Experiments 1 and 2 are consistent with Wagner's (1976, 1981) suggestion that a primed stimulus

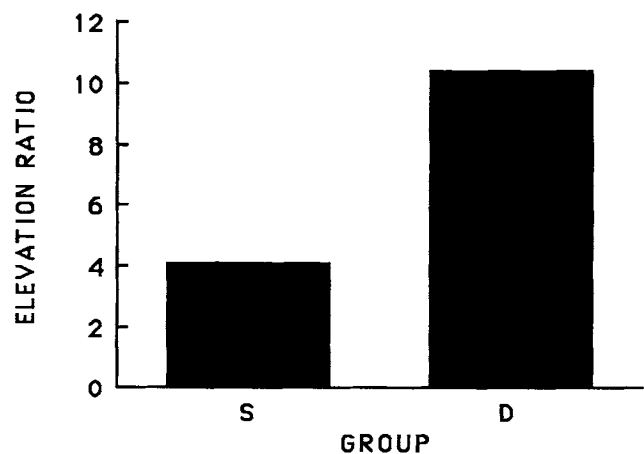


Figure 2. Experiment 2: Mean elevation ratios during the second, target elements of the serial compounds for the same (S) group (A-X and B-Y) and the different (D) group (A-Y and B-X).

will be less effective than a surprising one. We should now consider an alternative account that makes use of the phenomenon of *summation*.

It is well established that if two CSs are presented simultaneously, they will elicit a larger CR than when one or other of them is presented alone (e.g., Bellingham, Gillette-Bellingham, & Kehoe, 1985). Such summation is usually explained by assuming that the magnitude of the CR depends on the extent to which the US representation is being activated and by supposing that two CSs will activate the US representation more successfully than will one CS. A form of summation might be responsible for the results of Experiments 1 and 2. It has already been argued that during training, associations will develop between A and X and between B and Y and that these associations will allow A to activate a representation of X and B to activate one of Y. This will mean that after A has been presented on a D test trial, there will be two CS representations active, an associatively accessed representation of X and a directly accessed representation of Y. On S trials, however, the associatively accessed and directly accessed representations will match, and only one CS representation will be active, that of X. It is possible that such circumstances might result in summation on D trials—any CR elicited by the associatively accessed representation of X summing with the CR elicited by Y.

This interpretation of the results of Experiments 1 and 2 is neither uninteresting nor inconsistent with Wagner's (1981) theory. The theory allows that the associatively accessed (A2) representation of a CS could result in a (rather weak) CR; also, this CR might summate with the CR elicited by another CS. However, this interpretation would not require accepting the idea that X was any less capable of eliciting a CR as a result of being signaled by A. In Experiment 3, therefore, we attempted to establish whether the effect that was observed in Experiments 1 and 2 will occur when the potential for any contribution from such a summation effect has been removed.

There were two groups of rats in the experiment. One group, the X+/Y+ group, received the same training as subjects in Experiment 1: appetitive conditioning trials with A-X and B-Y followed by S and D test trials. These subjects can be expected to show more responding to the target on a D trial (e.g., to X on a B-X trial) than on an S trial (e.g., A-X). If this effect is a consequence of summation in the way just described, then it should be absent in a group that had received the same initial training but with presentations of B-Y not reinforced. In such a group (the X+/Y- group), the representation of Y will have no CR-generating properties that are not already possessed by X—that is, any tendency for Y to elicit responding will be the result of generalization from X. Consequently, the fact that a representation of Y will be active on a D test trial would not be expected to result in summation. If, however, the results of Experiments 1 and 2 are instances of a priming effect, then X should command more processing on a D than on an S trial, and the CR should be greater on the former than the latter trial types even in the X+/Y- group.

Method

The subjects were 16 naive male hooded Lister rats with a mean ad lib weight of 407 g (range = 335–450 g). The rats were maintained in the same way as Experiments 1 and 2. The apparatus was identical to that used in Experiments 1 and 2.

After magazine training, subjects received presentations of A-X and of B-Y. In both groups, X+/Y+ and X+/Y-, the tone served as X and the noise served as Y. In the former group, presentations of X and Y were followed by the delivery of a food pellet, whereas in the latter group only presentations of X were reinforced. In the test, subjects received two presentations of X, one preceded by A (the S trial) and the other preceded by B (the D trial). Half the subjects in each group received the sequence SD, and the remainder were given the sequence DS. Details of Experiment 3 that have not been mentioned were identical to those described for Experiment 1.

Results

Subjects in both of the groups came to respond during the reinforced compounds, A-X and B-Y, in the X+/Y+ group and during A-X in the X+/Y- group. The mean elevation ratios on the final pairs of trials on the last day of training (pooling responding for first and second elements) were 5.26 during A-X trials and 5.22 on B-Y trials; these scores did not differ ($F < 1$). Unsurprisingly, the X+/Y- group was more likely to respond during A-X trials, with a mean score of 6.83, than B-Y trials, with a mean score of 3.97, $F(1, 7) = 6.90$. The background rates of responding during training that were used to calculate these ratios, with means of 2.1 RPM for the X+/Y+ group and 1.03 RPM for the X+/Y- group, did not differ, $F(1, 14) = 2.04$.

During the test, there was some tendency for subjects to respond at a higher rate during the first element of the D trial, with means of 8.64 for the X+/Y+ group and 4.27 for the X+/Y- group, than the first element of the S trial, with means of 4.23 and 1.57 for the X+/Y+ and X+/Y- groups, respectively. Statistical analysis showed that these differences were not statistically significant. An ANOVA with group and trial type as the factors revealed no effect of group, $F(1, 14) = 1.56$, no effect of trial type, and no interaction between these factors ($F_s < 1$). In fact, the mean of 8.64 was entirely a consequence of 1 subject's score—on removal of this subject's score, the mean for the remaining subjects was 2.69.

Figure 3 depicts the critical results from Experiment 3: the levels of responding during X as a function of whether X had been preceded by A or by B. For 1 subject in the X+/Y- group, the flap that covered the food tray became jammed during the test session, and no scores were recorded for this animal. This subject's test scores were, therefore, replaced with the mean scores for the rest of the group. Figure 3 shows that the elevation scores were somewhat lower in the X+/Y- group than in the X+/Y+ group but that in both groups responding was more vigorous on the D trial than on the S trial. Statistical analysis confirmed this impression. An ANOVA with group and trial type (S or D) revealed an effect of trial type, $F(1, 14) = 4.19$, $p = .06$, no effect of group, and no interaction between these factors (largest $F = 1.28$). A parallel analysis of the absolute response rates during X revealed a similar pattern. Thus, the

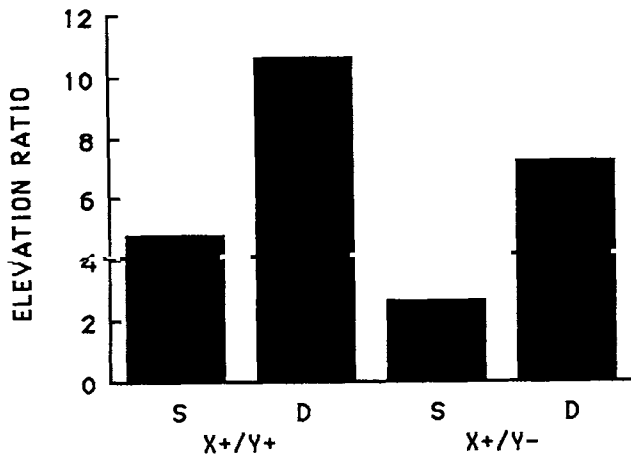


Figure 3. Experiment 3: Mean elevation ratios during the second element, X, of the same (S) serial compound (A-X) and the different (D) serial compound (B-X) for the X+/Y+ and X+/Y- groups. (Plus indicates delivery of a food pellet, and minus indicates no reinforcement.)

X+/Y+ group was more likely to respond on the D trial, with a mean of 11.75 RPM, than on the S trial, with a mean of 7.75 RPM, as was the X+/Y- group, with means of 9.71 and 4.57 RPM, respectively. An ANOVA confirmed that there was a significant effect of trial type, $F(1, 14) = 5.05$, and that there was no effect of group and no interaction between group and trial type ($F_s < 1$).

The mean rates of responding used to calculate the elevation ratios during the test were 1.98 and 2.25 for the S trials in the X+/Y+ and X+/Y- groups, respectively; and 1.42 and 1.90 for the D trials in the X+/Y+ and X+/Y- groups, respectively. Statistical analysis revealed no effect of group or trial type and no interaction between these factors ($F_s < 1$).

Discussion

The results of the X+/Y+ group confirm those of Experiments 1 and 2. The CR to X was less vigorous when it was signaled by a cue, A, that had also signaled it during training, than when X was presented after a cue, B, that had preceded some other CS, Y, during training. The new results, for the X+/Y- group, allow a choice to be made between rival explanations for this effect.

According to one interpretation, the effect depends on the associative strength governed by Y. During training, a B-Y association is likely to be formed. Responding might then be more evident when X follows B than when it follows A, because in the first case there could be two sources of conditioned responding—that elicited by X and that elicited by the associatively accessed representation of Y. Now the X+/Y- group received the same training as the X+/Y+ group except that Y was not reinforced during training. For these subjects, too, B may well become able to activate a representation of Y, but this would not be expected to generate responding because Y would lack associative strength. We found, however, that the test performance of the X+/Y-

group was very similar to that of the X+/Y+ group. We conclude, therefore, that the effect seen in these subjects, in the X+/Y+ group, and in the equivalent conditions of Experiments 1 and 2 is better interpreted as reflecting a reduced ability in a CS to evoke its CR when it is expected on the basis of a prime.

General Discussion

A recurring principle in Wagner's theorizing (e.g., 1976, 1978, 1981) has been that surprising events are better able to engage the processing mechanisms necessary for association formation and for performance than are predicted events. Blocking and the conditioned diminution of the UR have been taken as demonstrating these effects for USs. The context specificity of latent inhibition has been interpreted as showing that an unexpected event is better able to acquire strength as a CS than is an expected event. The results reported here appear to be the first relatively direct demonstration that a CS that has been predicted is less effective at evoking its CR than one that has not been predicted. After conditioning with a serial compound, A-X, conditioned responding during X was less evident when X was preceded by A than when it was preceded by B.

The theoretically neat pattern just outlined grows more complex when experiments on the context specificity of conditioned responding are considered. Latent inhibition shows context specificity, it is argued, because an association is formed between the context and the to-be-conditioned stimulus during preexposure. This association means that the stimulus will be primed by contextual cues during conditioning and will thus be poor at forming an association.

If a context-stimulus association can be formed during latent inhibition training, then it seems reasonable to assume that such an association, between context and CS, could also be formed during reinforced training. It follows that after conditioning, the CS will be primed by the context, and its ability to elicit the CR will be restricted. Presenting the CS in a different context should eliminate or attenuate this negative-priming effect and, other things being equal, the magnitude of the CR should be increased. As we have already noted, however, this result has rarely been obtained; if anything, a change of context tends to reduce the magnitude of the CR. Context specificity of the CR has been observed in experiments that are not only formally identical to those reported earlier but also make use of similar training procedures. For example, Hall and Honey (1989) gave rats appetitive conditioning (as in the present experiments) in which a series of clicks signaled food in one distinctive context (A) and a different stimulus (darkness) signaled food in a second context (B). When given the D test (Y in A and X in B), the subjects showed a reduced level of responding, not the increase seen in the studies that we report here.

We can only speculate at this stage as to why these two very similar experiments should produce such different results—a negative-priming effect in this article and context specificity of the CR in the experiments by Hall and Honey

(1989). One clear difference between the two sets of studies is that in the experiments reported here, the target cue (X) was reliably predicted by the priming cue (A), the latter occurring only immediately before the former. In the experiments on context specificity, however, the contextual cues (A) are often experienced in the absence of X—conditions that are unlikely to be conducive to the development of particularly powerful A-X and B-Y associations. The suggestion that the negative-priming effect depends on the strength of these associations carries with it the implication that the likelihood of observing this effect will be reduced under such conditions.

What this interpretation does not explain is why conditions that degrade the contingency between A and X and between B and Y should not merely abolish but actually reverse the negative-priming effect, that is, produce context-specific conditioned responding. One possibility is that some quite different mechanism is responsible for context specificity, a mechanism that might operate in all the training procedures considered here but will be able to show itself only when conditions are such as to minimize the role of associatively based negative priming. The obvious candidate for this mechanism is some form of conditional learning such as has been postulated to occur in occasion setting (e.g., Holland, 1983; see also Bouton, 1990; Hall, 1991). Thus, in addition to forming the various direct associations among the cues that are possible with our training procedure, subjects may also learn some form of the rule *X predicts food if A is, or has just been, present*. Animals in possession of this sort of information might be more likely to show responding to X in the presence of A than when A is absent. It is worth noting that presentations of A alone, although they will weaken the direct A-X associations, do not violate the rule.

It may be thought unparsimonious to introduce two learning (or performance) principles here, an associative one to deal with the negative-priming effect and a second, some form of conditional learning, to accommodate context specificity. There is however, evidence from a rather different source to support the suggestion. In a study of rats with hippocampal lesions, Good and Honey (1991) demonstrated that these animals showed a deficit in learning a conditional discrimination in which Stimulus X was reinforced in Context A but nonreinforced in Context B; they were, however, unimpaired in learning a Pavlovian discrimination in which food was delivered in Context A but not in Context B. The implication of this result is that hippocampal rats possess the mechanism that is responsible for the development of context-stimulus associations but not the mechanism subserving context-specific conditioning.

Finally, accepting that the context can function as a conditional cue prompts a reconsideration of the evidence on the context specificity of latent inhibition. This was interpreted by Wagner (1976) as being a priming effect dependent on the direct association between the context and the preexposed CS. However, an alternative (or additional) source of the effect now becomes apparent. Latent inhibition might show context specificity because the preexposure context acquires conditional, occasion-setting properties

(see Hall, 1991, for a full discussion of this suggestion). Some evidence to support this alternative comes from the observation that latent inhibition is able to survive a procedure (in which the subject experiences the context in the absence of the target stimulus) designed to weaken the direct context-stimulus association (Hall & Minor, 1984).

These speculations aside, the results reported in this article, coupled with those reported elsewhere, allow us to conclude two things. The first is that there may well be a variety of modulatory processes playing a role in determining the effectiveness of a given CS; the second is that among these processes should be numbered a negative-priming effect that depends on the integrity of a direct association between the CS and some other event that reliably predicts it.

References

- Allport, D. A., Tipper, S. P., & Chmiel, N. R. J. (1985). Perceptual integration and postcategorical filtering. In M. I. Posner & O. M. Marin (Eds.), *Attention and performance XI* (pp. 107-132). Hillsdale, NJ: Erlbaum.
- Bellingham, W. P., Gillette-Bellingham, K., & Kehoe, E. J. (1985). Summation and configuration in patterning schedules with the rat and rabbit. *Animal Learning & Behavior*, *13*, 152-164.
- Bouton, M. E. (1990). Context and retrieval in extinction and in other examples of interference in simple associative learning. In L. W. Dachowski & C. F. Flaherty (Eds.), *Current topics in animal learning: Brain, emotion, and cognition* (pp. 25-53). Hillsdale, NJ: Erlbaum.
- Channell, S., & Hall, G. (1983). Contextual effects in latent inhibition with an appetitive conditioning procedure. *Animal Learning & Behavior*, *11*, 67-74.
- Good, M., & Honey, R. C. (1991). Conditioning and contextual retrieval in hippocampal rats. *Behavioral Neuroscience*, *105*, 499-509.
- Hall, G. (1991). *Perceptual and associative learning*. Oxford, England: Clarendon.
- Hall, G., & Honey, R. C. (1989). Contextual effects in conditioning, latent inhibition, and habituation: Associative and retrieval functions of contextual cues. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 232-241.
- Hall, G., & Minor, H. (1984). A search for context-stimulus associations in latent inhibition. *Quarterly Journal of Experimental Psychology*, *35B*, 95-107.
- Holland, P. C. (1983). "Occasion-setting" in conditional discriminations. In M. L. Commons, R. J. Herrnstein, & A. R. Wagner (Eds.), *Quantitative analyses of behavior: Discrimination processes* (Vol. 4, pp. 183-206). New York: Ballinger.
- Kamin, L. J. (1969). Predictability, surprise, attention and conditioning. In B. A. Campbell & R. M. Church (Eds.), *Punishment and aversive behavior* (pp. 279-296). New York: Appleton-Century-Crofts.
- Kaye, H., & Mackintosh, N. J. (1990). A change of context can enhance performance of an aversive but not of an appetitive conditioned response. *Quarterly Journal of Experimental Psychology*, *42B*, 113-134.
- Kimmel, H. D., & Pennypacker, H. S. (1962). Conditioned diminution of the unconditioned response as a function of the number of reinforcements. *Journal of Experimental Psychology*, *68*, 567-572.
- Lovibond, P. F., Preston, G. C., & Mackintosh, N. J. (1984). Context-specificity of conditioning and latent inhibition. *Journal*

of *Experimental Psychology: Animal Behavior Processes*, 10, 360-375.

Mackintosh, N. J. (1975). A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review*, 82, 276-298.

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review*, 87, 532-552.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory* (pp. 64-99). New York: Appleton-Century-Crofts.

Wagner, A. R. (1976). Priming in STM: An information processing mechanism for self-generated and retrieval-generated depression

in performance. In T. J. Tighe & R. N. Leaton (Eds.), *Habituation: Perspectives from child development, animal behavior, and neurophysiology* (pp. 95-128). Hillsdale, NJ: Erlbaum.

Wagner, A. R. (1978). Expectancies and the priming of STM. In S. H. Hulse, H. Fowler, & W. K. Honig (Eds.), *Cognitive processes in animal behavior* (pp. 177-209). Hillsdale, NJ: Erlbaum.

Wagner, A. R. (1981). SOP: A model of automatic memory processing in animal behavior. In N. E. Spear & R. R. Miller (Eds.), *Information processing in animals: Memory mechanisms* (pp. 5-47). Hillsdale, NJ: Erlbaum.

Received December 11, 1991
 Revision received August 10, 1992
 Accepted August 18, 1992 ■



Statement of Ownership, Management and Circulation
 (Required by 39 U.S.C. 3685)

1A. Title of Publication Journal of Experimental Psychology: Animal Behavior Processes		1B. PUBLICATION NO. 0 8 6 5 5 0		2. Date of Filing 9/22/92
3. Frequency of Issue Quarterly	3A. No. of Issues Published Annually 4	3B. Annual Subscription Price \$21/Member \$50/Indv., \$ 100/Inst.		
4. Complete Mailing Address of Known Office of Publication (Street, City, County, State and ZIP + 4 Code) (Not printers) 750 First Street, NE, Washington, DC 20002-4242				
5. Complete Mailing Address of the Headquarters of General Business Offices of the Publisher (Not printer) 750 First Street, NE, Washington, DC 20002-4242				
6. Full Name and Complete Mailing Address of Publisher, Editor, and Managing Editor (This item MUST NOT be blank) Publisher (Name and Complete Mailing Address) American Psychological Association, 750 First Street, NE, Washington, DC 20002-4242 Editor (Name and Complete Mailing Address) Stewart H. Hulse, Ph.D., The Johns Hopkins University, Dept. of Psychology, Ames Hall, Baltimore, MD 21218 Managing Editor (Name and Complete Mailing Address) Susan Knapp, 750 First Street, NE, Washington, DC 20002-4242				
7. Owner (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding 1 percent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a partnership or other unincorporated firm, its name and address, as well as that of each individual must be given. If the publication is published by a nonprofit organization, its name and address must be stated.) (This must be completed.)				
Full Name American Psychological Association		Complete Mailing Address 750 First Street, NE Washington, DC 20002-4242		
8. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages or Other Securities. (If there are none, so state) NONE				
9. For Completion by Nonprofit Organizations Authorized to Mail at Special Rates (28M Section 424.12 only) The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes (Check one) (1) Has Not Changed During Preceding 12 Months <input type="checkbox"/> (2) Has Changed During Preceding 12 Months <input type="checkbox"/> (If changed, publisher must submit explanation of change with this statement.)				
10. Extent and Nature of Circulation (See instructions on reverse side)		Average No. Copies Each Issue During Preceding 12 Months		Actual No. Copies of Single Issue Published Nearest to Filing Date
A. Total No. Copies (Net Press Run)		3,637		2,940
B. Paid and/or Requested Circulation 1. Sales through dealers and carriers, street vendors and counter sales		1,405		1,406
2. Mail Subscriptions (Paid and/or requested)		686		578
C. Total Paid and/or Requested Circulation (Sum of B1 and B2)		2,091		1,984
D. Free Distribution by Mail, Carrier or Other Means Samples, Complimentary, and Other Free Copies		83		73
E. Total Distribution (Sum of C and D)		2,174		2,057
F. Copies Not Distributed 1. Office use, left overs, unaccounted, spoiled after printing		1,463		883
2. Return from News Agents		-----		-----
G. TOTAL (Sum of E, F1 and F2—should equal net press run shown in A)		3,637		2,940
11. I certify that the statements made by me above are correct and complete		Signature and Title of Editor, Publisher, Business Manager, or Owner K. K. Yamoto, Director, Publishing Services		