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Blocking of conditioned suppression with 1 or 10 compound trials

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It is generally agreed that the Kamin blocking effect provides a differential test of the model of classical conditioning proposed by Rescorla and Wagner (1972), on the one hand, and the models proposed by Mackintosh (1975) and Pearce and Hall (1980), on the other. Specifically, if the blocking effect occurs with 1 compound trial, Rescorla and Wagner are supported. Experiment 1 showed that prior training with one element of a simultaneous compound stimulus prevented the added element from becoming conditioned with 10 compound trials when compared with a nonpretrained (Kamin) control. A pseudoconditioning control, which received no compound training, showed substantial suppression only on the first trial. A contextual conditioning control, which received unsignaled shock prior to compound training, was suppressed, suggesting a failure of conditioning to contextual cues. Experiment 2 demonstrated 1-compound-trial blocking using a simultaneous presentation of the compound elements. The importance of this support for the Rescorla-Wagner model is discussed in the light of other supportive studies and those which support alternative models of classical conditioning.

One element, *X*, of a compound conditioned stimulus (CS) may fail to become conditioned because of prior pairings of the other element, *A*, with the unconditioned stimulus (US). That is, element *A* blocks conditioning to element *X* during *AX* US trials. This phenomenon, first described by Kamin (1969), has generated a considerable amount of research and inspired several theories of classical conditioning. Rescorla and Wagner (1972) proposed a model which describes the negatively accelerated learning curve typically obtained in conditioning experiments. Their model assumes that on a given trial associative strength accrues to a CS proportional to the asymptotic level of conditioning (determined by the US intensity) minus the associative strength gained on all previous trials. The largest increment in association occurs on the first trial, followed by successively smaller amounts on subsequent trials. Blocking occurs, according to Rescorla and Wagner, because prior conditioning to element *A*, if it is at asymptote, has acquired virtually all the conditioning available with the US in use; there is little or no conditioning left which might accrue to *X*, the element added during compound training. This model predicts that if the number of US presentations or US intensity is increased during compound training, allowing for more conditioning, *X* will acquire associative strength and blocking will be attenuated. This prediction was born out in the original experiments of Kamin (1969) and later in the experiments of Dickinson, Hall, and Mackintosh (1976) and Mackintosh, Bygrave, and Picton (1977).

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The Rescorla-Wagner model emphasizes the processing of the US in establishing CS-US associations. Mackintosh (1975a) proposed an alternative interpretation of classical conditioning in terms of attentional and informational processes. Specifically, he suggested that the associability of a CS is determined by how well it predicts reinforcement. The best predictor of the US receives the most attention and therefore acquires the most associative strength. This process is assumed to occur proactively. The CS that best predicts the US on Trial *N* is the most attended to on trial $N+1$ and receives the most conditioning on that trial. Blocking occurs, according to Mackintosh, because *A*, the original element, has become the best predictor of the US. Attention to element *X*, which is a relatively poor predictor of the US, rapidly declines during compound training, resulting in little conditioning. Because this decline in attention to the added element is proactive, that element will acquire some associative strength on the first compound trial. A straightforward prediction from this model is that blocking will not occur with only one compound training trial. This prediction does not derive from the Rescorla-Wagner model, which clearly predicts blocking with one compound trial. Although it is true, within this model, that whatever conditioning accrues to the added element would be greatest on the first compound trial, it would be negligible if conditioning to the first element were asymptotic.

Pearce and Hall (1980) presented yet another model of classical conditioning which, like the Mackintosh model, predicts the failure of blocking with one compound trial. By this account, a CS loses associability as it becomes more predictive of the US. After numerous CS-US pairings, processing occurs in an automatic mode. Blocking occurs because the added element predicts nothing new and also gets processed automatically. However, one compound trial is required to establish the redundancy of the added element, and conditioning to this element is predicted with one compound trial.

There is little doubt that the occurrence of blocking with one compound trial is of pivotal importance in evaluating these alternative conceptions of classical conditioning. Unfortunately, the evidence is equivocal. Mackintosh and his colleagues have failed to demonstrate blocking with one compound trial (e.g., Dickinson, Nicholas, & Mackintosh, 1983; Mackintosh, 1975b; Mackintosh, Dickinson, & Cotton, 1980), except when the elements of the compound CS were presented sequentially and separated by a trace interval (Dickinson et al., 1983, Experiment 3). Revusky (1971) and Gillan and Domjan (1977) obtained blocking of a conditioned taste aversion with one compound trial. Here, again, the elements of the compound were sequenced in compound conditioning with a time interval between them. The only published demonstration of one-compound-trial blocking, using simultaneously presented compound stimuli in a conditioned suppression procedure, is that of Balaz, Kasprow, and Miller (1982).

The purpose of the present study was to provide further evidence on the one-trial-blocking issue. The first experiment attempted to demonstrate the Kamin blocking effect (with several compound trials) using the procedures with which it has been reliably demonstrated. A secondary purpose was to evaluate three different control procedures against which to compare a group receiving blocking treatment. Specifically, the conditioned suppression of a drinking response was used to assess the differential response of a blocked group relative to the most commonly used control procedure, namely the control devised by Kamin (1969), in which only training with the compound CS is provided. A second control group was run to test the possibility that the blocking demonstrated in the blocked group might be due to the decrease in the effectiveness of the shock with increased conditioning trials (see Randich & LoLordo, 1979). This group received unsignaled shock prior to compound training. This procedure would also be a simple test of contextual cue blocking (see Ayres, Bombace, Shurtleff, & Vigorito, 1985). A third control group was included to test the possibility that the frequently obtained suppression on the first test trial in otherwise blocked groups (see Mackintosh, 1975b; Mackintosh et al., 1977; Rescorla & Colwill, 1983) was due to pseudoconditioning. This group received pretraining with the blocking CS only, with the added element presented during test trials for the first time.

EXPERIMENT 1

Method

Subjects. Twenty-four male Wistar rats were used in this experiment. They were approximately 90 days old and weighed between 290 and 310 g at the start of the experiment.

Apparatus. The conditioning chamber was 31 cm long and 15.5 cm wide and high. The long walls were constructed of aluminum, and the short walls and top of Plexiglas. The floor was constructed of 0.23-cm stainless steel rods. In one Plexiglas wall was a circular 1-cm-wide hole located 5.5 cm above the floor. This provided the rat with access to an electrically insulated drinking tube connected through a drinkometer circuit to the grid floor. Drinking, which closed the circuit, was recorded by an Apple II computer, which was also programmed to present all stimulus conditions during pretraining, conditioning, and testing.

The CS was either white noise or light. The noise was presented from a 17-cm speaker located 48 cm above the grid floor. Noise onset increased the ambient sound level from 41 to 81 dB (scale B). The light CS was provided by two 6-W bulbs located 45 cm above the floor. The US was a 2-sec, 100-V ac scrambled footshock delivered by a 150-kΩ fixed impedance source. The conditioning chamber was enclosed in a sound-attenuating box.

Procedure. The subjects were assigned randomly to one of four equal-sized groups and deprived of water for 24 h before the experiment. On Day 1, the subjects were placed in the apparatus and given 20-min access to the drinking tube. Conditioning trials were given on Days 2–4. On these days, the subjects were first given 20-min access to the drinking tube, and this made up their daily water ration. After 20 min, the drinking tube was removed. Five minutes later, conditioning began. A conditioning trial consisted of a 10-sec CS interval, during the last 2 sec of which shock was presented. At that point, the CS and US coterminated. There was an intertrial interval (ITI) of 45 sec.

The experimental treatments are summarized in Table 1. Pretraining was conducted on Days 2 and 3. The blocked group (B) and the pseudoconditioned group (PC) received 10 noise-shock pairings on each pretraining day. The unsignaled control (UC) received 10 unsignaled shock presentations in a pattern identical to that of Groups B and PC. The Kamin control (KC) received no CS or US presentation during pretraining; after 20 min access to water, the drinking tube was removed and these subjects remained in the apparatus for a length of time comparable to that used with the other groups.

Training with the compound CS was given on Day 4. Groups B, KC, and UC received 10 trials of a simultaneous noise-and-light compound CS followed by shock in a pattern identical to that used in pretraining. Group PC received 10 noise CS-US trials.

On Day 5, all groups were tested for conditioned suppression to the light CS. A subject was placed in the apparatus, and, after it emitted 400 licks, the test trials were begun. The first 10 sec of a trial constituted a baseline interval. The CS was then presented for 10 sec without the US. The number of licks in each interval was recorded in order to compute suppression ratios [$A/(A+B)$, where A equals the number of licks during the CS interval and B equals the licks during the baseline period]. The intertrial interval was 35 sec, making the temporal pattern of CS presentations identical to that of training (baseline interval + ITI = 45 sec). There were four test trials.

Results and Discussion

The results of Experiment 1 are presented in Figure 1, which shows mean suppression ratios as a function of test trials on which the light was the test stimulus. All groups appear to be suppressed on the first trial. Groups B and PC show a rapid release from suppression between

Table 1
Summary of Experimental Treatments (Experiment 1)

	Pretraining		Compound Training	Test
Group	Day 2	Day 3	Day 4	Day 5
B	10N+	10N+	10NL+	L
KC			10NL+	L
UC	10+	10+	10NL+	L
PC	10N+	10N+	10N+	L

Note—B, blocked; KC, Kamin control; UC, unsignaled control; PC, pseudoconditioning control. N = noise CS; L = light CS; + = US.

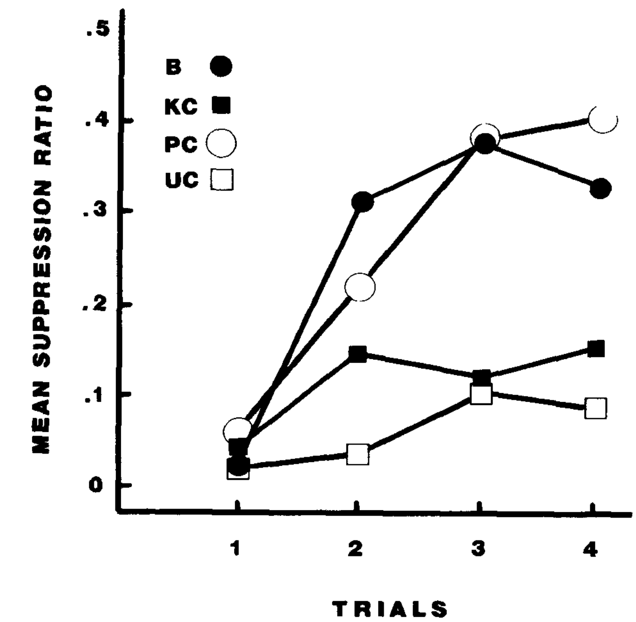

Figure 1. Mean suppression ratios as a function of test trials. B, blocking; PC, pseudoconditioning control; KC, Kamin control; UC, unsignaled shock control.

Trials 1 and 2 and continue to respond at a high rate during the CS interval on the remaining trials. Groups KC and UC also show some release from suppression over test trials but remain fairly suppressed throughout testing. A 4 × 4 mixed-design ANOVA (pretraining × trials treated as repeated measures) revealed a significant main effect for pretraining [$F(3,20) = 7.35$, $p < .01$] and trials [$F(3,60) = 11.76$, $p < .01$]. The pretraining × trials interaction was not significant. Newman-Keuls tests, conducted post hoc ($p < .05$), revealed that Groups B and PC did not differ and Groups KC and UC did not differ. Furthermore, Groups B and PC were each different from both Group KC and Group UC. The finding that Group B was less suppressed than Group KC is a clear demonstration of the blocking phenomenon.

The fact that Groups KC and UC were equally suppressed suggests that neither decreased effectiveness of shock (Randich & LoLordo, 1979) nor contextual conditioning (Ayres et al., 1985) served to eliminate conditioning in the UC group. Apparently, the specific procedures used in the present experiment were not those necessary for producing these effects. The finding that the light CS suppressed licking in Group PC on the first test trial even though the light was a novel stimulus suggests that the substantial suppression often observed on the first test trial in the blocking literature may be due to pseudoconditioning. Although it is possible that this conditioning reflects generalization between the noise and light, the fact that these two stimuli are in different sensory modalities suggests that pseudoconditioning is the best interpretation. If this is true, studies that attempt to evaluate suppression specific to the CS may require more than one or two test trials.

EXPERIMENT 2

Experiment 1 provided clear evidence that substantial blocking can be demonstrated using the chosen conditioning procedures when blocking is measured relative to either an unsignaled shock control or the original blocking control (Kamin, 1969). Having accomplished this, Experiment 2 was designed to use the same stimulus parameters in an attempt to show that blocking can occur after one compound trial when the elements of the compound CS are presented simultaneously. The manner in which the compound is presented may be critical to one-compound-trial blocking. The studies that have reported a failure of this phenomenon (Dickinson et al., 1983, Experiment 1; Mackintosh, 1975b; Mackintosh et al., 1980) all used a simultaneous presentation of the compound elements. The latter study also failed to find one-trial blocking when the elements were sequenced, with the blocking CS immediately following the blocked CS. The demonstrations of one-compound-trial blocking of a conditioned taste aversion (Revusky, 1971; Gillan & Domjan, 1977) presented the compound taste elements sequentially, with an interval between them. A recent demonstration of one-compound-trial blocking of conditioned suppression was achieved only after the blocked CS, presented first, was separated from the blocking CS by a trace interval (Dickinson et al., 1983, Experiment 3). As far as we can determine, the study by Balaz et al. (1982) is the only published demonstration of one-compound-trial blocking in which the compound elements were simultaneous. In some respects, the Balaz et al. experiment is a convincing demonstration of this phenomenon. However, because it is the only demonstration, two procedural questions must be raised. First, it is possible that their blocking control group may have been suppressed because of generalization between the clicker CS used in pretraining and the tone CS use in compound training and as the test CS. Their nonassociative control, used in part to check this possibility, was given a nonreinforced presentation of the tone which conceivably reduced its effectiveness. Second, although their measure of conditioning (log latency to emit 25 licks) may avoid some of the problems associated with the suppression ratio (see Hurwitz & Davis, 1983), it is not a common measure of conditioning in the blocking literature or the measure used in studies that failed to demonstrate one-compound-trial blocking.

Experiment 2 was conducted to demonstrate one-compound-trial blocking with a simultaneous presentation of the compound CS elements. The control procedure devised by Kamin (1969) was selected because it remains the most common in the field and was the one used in the initial failure of one-compound-trial blocking (Mackintosh, 1975b).

Method

Subjects. Eighteen male Wistar rats were used as subjects. They were approximately 90 days old and weighed about 300 g.

Apparatus. The apparatus used was identical to that of Experiment 1.

Procedure. The procedure used in this experiment was the same as that used in Experiment 1 except that compound training was limited to one trial. The subjects were assigned randomly to one of two groups. Group B received 10 noise-shock pairings on each pretraining day. Group KC remained in the conditioning chamber for the same amount of time that Group B spent there on pretraining days, but received no CS or US. On Day 4, both groups received one trial with the compound CS (light/noise) followed by shock. All subjects were given four test trials for conditioned suppression to the light on Day 5.

Results and Discussion

The suppression ratios, computed as in Experiment 1, are presented in Figure 2 for the B and KC groups over the four test trials. These data clearly suggest that after the first test trial, on which both groups were suppressed, Group B showed little suppression to the light element of the compound. However, Group KC, although evidencing some decrease in suppression over the four test trials, remained fairly suppressed throughout testing. A 2 × 4 ANOVA (pretraining × trials) was performed on these data, with trials treated as repeated measures. Pretraining had a significant effect on suppression scores [$F(1,16) = 4.68$, $p < .05$]. Suppression scores also decreased significantly as trials progressed [$F(3,48) = 4.81$, $p < .01$]. The interaction was not significant.

These results show quite clearly that, although suppression decreased across test trials, probably due to extinction, the suppression produced in the KC group was substantially greater than that of the B group. This was true even though the results were somewhat mitigated by the inclusion of the first test trial, which, if we can draw upon the results of the pseudoconditioning group of Experiment 1, was affected by nonassociative suppression. Additionally, the low suppression in the blocked group indicates that the relatively high intensity of the noise CS did not result in the formation of within-compound (noise-light) associations which would have masked the blocking effect.

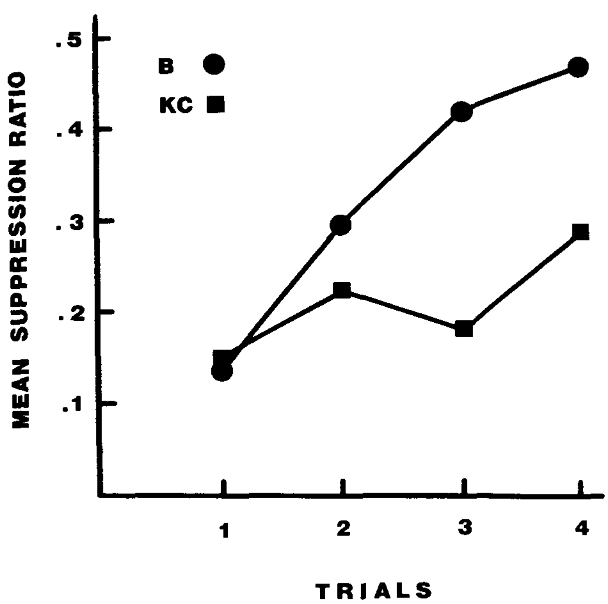

Figure 2. Mean suppression ratios as a function of test trials. B, blocking; KC, Kamin control.

At this point, it is critical to examine the baseline licking rates to eliminate the possibility that the blocking obtained in this experiment was due to a depressed licking rate in Group B. A depression in the baseline rate could result in little opportunity for the added CS to suppress the lick response. This would result in the appearance of blocking where blocking might not be occurring. To evaluate this possibility, a 2 × 4 ANOVA (groups × trials) was performed on the number of licks during the 10-sec period preceding the CS during the four test trials. This analysis showed a significant difference between Groups B and KC [$F(1,16) = 6.47$, $p < .05$], but this difference was in a direction which would serve to reduce the differences in suppression between the groups. That is, the baseline rates were slightly higher in Group B than in Group KC. The lower baseline rates in Group KC resulted in an inflation of their suppression ratios, yet these were still much lower than those of Group B.

These findings provide strong support for the Rescorla-Wagner (1972) model of classical conditioning and speak against the models proposed by Mackintosh (1975a) and Pearce and Hall (1980). Specifically, they provide support for the view that in classical conditioning the processing of the US initiates a retroactive scanning of the prior CS presentation. In the event that some element of the CS entirely predicts the US, an added element does not become associated with the US. This associative failure is evident after only one trial. In addition, this experiment supports the finding of Balaz et al. (1982) that one-compound-trial blocking is not dependent upon a nonoverlapping, sequential presentation of the compound elements as suggested by Dickinson et al. (1983). It appears that any within-compound associations that might occur during simultaneous presentations of the compound elements in a blocking procedure (see Rescorla & Durlach, 1981) will not necessarily mask the associative failure between the added CS and the US after a single compound trial.

These two demonstrations of one-compound-trial blocking with a simultaneous compound are discrepant with the findings of Mackintosh and colleagues (Dickinson et al., 1983; Mackintosh, 1975b; Mackintosh et al., 1980), who have repeatedly demonstrated a failure of this phenomenon. Because of the importance of this issue to several theories of conditioning, further analysis of this discrepancy seems warranted.

Perhaps the first step in this analysis is an examination of the studies that reported a failure of one-compound-trial blocking. The original study by Mackintosh (1975b) was examined carefully. Experiments 1 and 2 of Mackintosh's study included groups of subjects which received one or eight compound trials following pretraining with one element of the compound. In Experiment 1, the blocked groups were equally unsuppressed with one and eight compound trials. That the eight-trial group was blocked and the one-trial group was not appears to have been defined in terms of the performance of their respective (Kamin) control groups. Controls that received eight compound trials were very suppressed, whereas those that received only one were equal in suppression to the one-compound-trial blocked group. This pattern of results was repeated in Experiments 2 and 3. In those experiments, both experimental and control groups that received one compound trial showed a similar lack of conditioning. This was interpreted by Mackintosh as a failure of blocking. An alternative interpretation is simply that the control group was not conditioned to the test CS with one compound trial. A similar analysis of Mackintosh et al. (1977, Experiment 3) and Mackintosh et al. (1980) shows that, in each case, blocked groups that received one compound trial showed as little or less conditioning than blocked groups that received more than one compound training trial. In each case, this is cited as evidence for the failure of one-compound-trial blocking when, in fact, it may simply show a failure of conditioning with one compound trial.

Dickinson et al. (1983, Experiment 1), however, demonstrated substantial conditioning in two blocking groups which received either a single simultaneous or single sequential presentation of the compound CS elements. The degree of conditioning was much greater in these blocked groups than it was in the studies cited above which report a failure of one-compound-trial blocking, and this result provides support for the theories of Mackintosh (1975a) and Pearce and Hall (1980). However, this finding is somewhat confused by the small amount of conditioning in the blocking control group. The relatively small amount of suppression elicited by the test CS (clicker) may be due to its having been presented in a compound with a CS (overhead light) that was presented without shock during pretraining. It is possible that the overhead light interfered with conditioning to the clicker during the single compound trial. If this is the case, then a comparison of this group and the blocked group is difficult to interpret.

The consistent failure of these studies to demonstrate much conditioning in blocking control groups may be due to the relatively long CS durations employed. Balaz et al. (1982) suggested that long-duration CSs might result in the formation of within-compound associations. If this were true, it would be expected that long-duration CSs would produce strong suppression in one-compound-trial blocking groups. However, the suppression scores of blocked groups that received one compound trial in those studies (e.g., Mackintosh, 1975b) were equal to or less than those of groups that received more than one compound trial. Because the blocking controls also showed little conditioning (Mackintosh, 1975b; Mackintosh et al., 1980), it is suggested that delay of reinforcement is responsible for the comparable conditioning found in blocked and control groups. That is, with a relatively long CS duration, one trial may not produce much conditioning. This possibility deserves empirical evaluation.

In sum, Experiment 2 is a straightforward demonstration of one-compound-trial blocking using procedures similar to those of past studies which failed to demonstrate the phenomenon. It lends further support to the finding of Balaz et al. (1982) that blocking with a single compound trial will occur with simultaneous presentation of the compound elements. Taken together, these two studies provide a strong confirmation of the prediction, made from the Rescorla-Wagner model, that a redundant CS will fail to acquire associative strength on the first compound conditioning trial.

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