Blocking and pseudoblocking: The reply of *Rattus norvegicus to Apis mellifera*

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Abstract

Blaser, Couvillon, and Bitterman (2006) presented data obtained with honeybees that in principle challenged all traditional interpretations of blocking. They administered A + followed by either A + or + alone (where + indicates an unconditioned stimulus) and then tested on X. They observed less responding to X when they administered A + than when + alone was administered, a phenomenon they called "pseudoblocking". Here we examined pseudoblocking in a rat fear-conditioning preparation. In Experiment 1, using a control procedure that was similar to our usual blocking control, we obtained conventional blocking but failed to observe pseudoblocking in our analogue to Blaser et al.'s procedure. In Experiment 2, we used Blaser et al.'s control procedure and again failed to observe the pseudoblocking effect with rats when we used the experimental context as an analogue to the honeybee feeder used by Blaser et al. After reviewing their protocol and previously published studies from their laboratory, we hypothesized that the feeder that they treated as a training context probably served as a punctate cue. We also tested this possibility in Experiment 2, using a punctate cue as a surrogate feeder, and were now able to reproduce their pseudoblocking phenomena. Our results are consistent with a simple overshadowing account of pseudoblocking, within the framework of existing theories of associative learning, which is not applicable to the conventional blocking paradigm. Thus, blocking remains a real phenomenon that must be addressed by models of associative learning.

Blocking has been a central phenomenon in the study of learning from the time it was first described by Kamin (1969). It has been demonstrated in a wide variety of organisms, ranging from humans to honeybees, fish, rats, and pigeons (Blaser, Couvillon, & Bitterman, 2004; Couvillon, Arakaki, & Bitterman, 1997; Tennant & Bitterman, 1975). Blocking can be described as follows: A blocking group receives a conditioned stimulus (CS), A, followed by an unconditioned stimulus (US) in Phase 1 of treatment. Then during Phase 2, a compound composed of A and the target CS (X) is paired with the US. A typical control group lacks the A–US pairings in Phase 1 and receives only the AX compound paired with the US in Phase 2. When the response potential of CS X is tested, the response to stimulus X is larger in the control group than in the blocking group. Thus, the conditioning of Stimulus A in the experimental group during Phase 1 is said to subsequently block either conditioning or responding to the CS X. Although providing an explanation of blocking has become a required benchmark for all associative models of learning, each model provides a different account of this biologically widespread phenomenon. Despite the different interpretations among contemporary models of learning (e.g., Gallistel & Gibbon, 2000; Miller & Matzel, 1988; Pearce, 1987; Rescorla &

Wagner, 1972; Wagner, 1981), all accounts assume that that the Phase 1 conditioning of A disrupts either learning about X in Phase 2 or expression at test of what was learned about X in Phase 2.

In a recent paper Blaser, Couvillon, and Bitterman (2006) reported a theoretically challenging effect that they called *pseudoblocking*. In their conditioned foraging experiment with honeybees, they obtained the same results that would be expected given a conventional blocking design; however, their test stimulus (X) was not presented during Phase 2. Instead subjects were exposed to the A–US pairing in Phase 2. This pseudoblocking procedure is illustrated in Table 1. In this table the pseudoblocking and the forward control groups were similar to the blocking and control groups, respectively, in a classical blocking design, except that for all groups the test stimulus X was never trained. None of the prevailing theoretical accounts of blocking can readily explain this pseudoblocking effect, and in fact on initial consideration all contemporary models of associative learning predict an absence of responding to the unconditioned target stimulus X for all groups because X was not present during training. But, due to the similarity of the results in the two designs (i.e., conventional blocking and pseudoblocking), it appears that training with the test stimulus in the conventional blocking design is unnecessary to obtain apparent blocking (see Table 1). Essentially, pseudoblocking is a confound that has not been controlled for in any of the many prior demonstrations of blocking. Blaser et al. rightly suggested that any account of the pseudoblocking effect might also be able to account for the conventional blocking effect, which would falsify the common assumption of all contemporary associative accounts of blocking that blocking depends on X being present during Phase 2 trials.

One such account that can apply to both pseudoblocking and blocking is that there could be more generalization to X in the control group(s) both from A (conditioned in the phase in which A was paired with the US) and from the context (conditioned in the phase lacking A), than in the pseudoblocking and blocking groups both from A (conditioned in both phases) and from the context (perhaps protected from conditioning by the presence of A in both phases). Such a generalization account of blocking is also consistent with blocking observed with the more common control group that receives reinforcement signalled by an irrelevant cue (C) instead of unsignalled reinforcement in Phase 1 (forward control) or Phase 2 (backward control). With this control treatment and AX + trials in Phase 2, generalization to X at test would be from two excitors, A and C, whereas in the blocking group, generalization would be only from A, the blocking cue. A generalization account of blocking (and pseudoblocking) would be consistent with most contemporary models of learning, but would circumvent the assumption of all contemporary theories that blocking reflects some sort of competition between A and X that occurs as a result of A and X being present in compound during Phase 2. Given the benchmark status of a model's ability to account for blocking in terms of some sort of cue competition, the reappraisal of conventional blocking as a form of pseudoblocking, perhaps due to differential stimulus generalization, is a major departure from the ways that blocking has been viewed ever since Kamin (1969) reported the phenomenon. This paper addresses the nature of pseudoblocking and how similar it actually is to conventional blocking. Specifically, we sought to replicate the pseudoblocking effect in rats using a fear-conditioning preparation and then to investigate its determinants.

EXPERIMENT 1

In our first experiment we investigated whether the pseudoblocking phenomenon could be replicated with rats in a fear-conditioning preparation using an analogue of the usual control procedure for blocking used in our laboratory, which includes presentations of B–US in Phase 1, thereby matching the pseudoblocking and the pseudoblocking control groups for total number of signalled USs received (see Table 2). Blaser et al. (2006) gave their control group

unsignalled USs in Phase 1 (see Table 1), which allowed the possibility of differential context conditioning across groups. Our blocking control group received USs in Phase 1 that were signalled by an irrelevant cue (C), the physical identity of which was counterbalanced with A. This should have equated the associative status of the conditioning context between groups blocking and blocking control, thereby correcting a problem with Blaser et al.'s demonstration of blocking.

In addition, we attempted to evaluate the claim of Blaser et al. that our usual blocking control procedure could lead to more generalization to the test stimulus (X) in the control group than in the blocking group. This expectation is based on the possibility that in the control group there is generalization from each of the two trained excitors (A and C) to X, whereas in the blocking group only A can generalize to X. Thus, the super generalization blocking group received both A–US and C–US pairings in Phase 1. According to Blaser et al. (2006) generalization to X from both A and C should have yielded strong stimulus control of behaviour by X. In contrast the superblocking group was matched for the number of signalled USs in Phase 1, but only experienced A paired with the US. The blocking and blocking control groups merely served to determine that the present procedures were adequate to produce conventional blocking.

In summary, the goals of this experiment were:

1. To replicate in rats the pseudoblocking phenomena using an analogue of a standard blocking control condition (see Table 2, groups pseudoblocking and pseudoblocking control).

2. To evaluate the generalization account of the blocking phenomena suggested by Blaser et al. (2006) using our blocking control condition (see all remaining groups in Table 2). If the generalization account of blocking offered by Blaser et al. is correct, one can make the following predictions: The apparent blocking effect should be attenuated if a second excitor (other than A) is trained in Phase 1 (group super generalization blocking). In comparison, blocking groups that do not receive training with another excitor (group blocking) or receive double training on A to equate the number of signalled shocks with group super generalization blocking (group superblocking) should not exhibit an attenuated blocking effect.

Method

Subjects—The subjects were 36 male (189–377 g) and 36 female (199–356 g) experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony in which animals are handled for 30 s three times a week from weaning until the initiation of the experiment. Subjects were randomly assigned to one of six groups (ns = 12), counterbalanced within groups for sex. Subjects were individually housed and were maintained on a 16-hr light/ 8-hr dark cycle. Experimental sessions occurred approximately midway through the light portion. Subjects had free access to food in the home cages. Prior to initiation of the experiment, water availability was progressively reduced to 15 min per day, provided approximately two hours after any scheduled treatment.

Apparatus—The apparatus consisted of 12 operant chambers, each measuring $30 \times 30 \times 27$ cm (length $\times$ width $\times$ height). The side walls of the chamber were made of stainless-steel sheet metal, and the front wall, back wall, and ceiling of the chamber were made of clear Plexiglas. On one metal wall of each chamber there was a 3.5-cm wide operant lever in the left side, 4 cm above the floor, and a niche ($2.5 \times 4.5 \times 4$ cm) in the right side, the bottom of which was 2 cm above the floor, where a drop (0.04 ml) of tap water could be presented by a solenoid valve into a small cup. The floor was constructed of 0.3-cm diameter rods spaced 1.3 cm centre

to centre and connected by NE-2 neon bulbs that allowed a constant-current footshock to be delivered by means of a high-voltage AC circuit in series with a 1.0-MΩ resistor. Each chamber was housed in an environmental isolation chest, which was dimly illuminated by a houselight (1.12 W, No. 1820 incandescent bulb) mounted on the left wall of the experimental chamber. Ventilation fans in each enclosure provided a constant 76-dB (C-scale) background noise. Three 45-Ω speakers mounted on the interior right, left, and back walls of each environmental chest were used to deliver the auditory stimuli.

Stimuli and counterbalancing—The stimuli A, C, and X were different auditory cues of 10 s duration during training; they were extended to 30 s during testing to provide a longer window in which to assess bar press rate. A and C, counterba-lanced within groups, consisted of a white noise and a complex tone (500 and 520 Hz), both 4 dB (C-scale) above background. Stimulus X was a 6-per-second click 6 dB (C-scale) above background. This higher intensity of X was intended to minimize overshadowing of X by A in the blocking control group, which would have masked any blocking effect that would otherwise have been manifest in a comparison between the blocking and blocking control groups. The US consisted of a 0.5-s, 0.7-mA footshock. The experimental boxes were counterbalanced across groups.

Procedure

Acclimation, shaping, and preexposure: On Days 1–5 acclimation to the apparatus, shaping of bar press behaviour, and preexposure to X (only on Day 5) were conducted in daily 1-hr sessions. Subjects were shaped to bar press for water on a variable-interval 20-s schedule in the following manner. On Days 1 and 2, a fixed-time 120-s schedule of noncontingent water delivery was in force concurrently with a continuous reinforcement schedule. On Day 3, noncontingent reinforcers were discontinued, and subjects were trained on the continuous reinforcement schedule alone. Subjects that made fewer than 50 responses on this day were scheduled to receive a hand-shaping session later in the same day (no subjects failed to meet this criteria). On Days 4 and 5 a variable-interval 20-s schedule was imposed. This schedule of reinforcement prevailed throughout the remainder of the experiment including testing, except for Phases 1 and 2 during which the levers were retracted. On Day 5 all subjects received two nonreinforced presentations of stimulus X in order to minimize unconditioned responding to X at test. To facilitate lever pressing, the houselight was turned off for 0.5 s each time water was delivered.

Phase 1: On Days 6–8 groups blocking, blocking control, pseudoblocking and pseudoblocking control received four presentations per day of their respective CS (see Table 2) followed immediately by the US during daily 1-hr sessions. Groups super generalization blocking and superblocking received eight presentations per day of their CS followed immediately by the US (+) during daily 2-hr sessions (i.e., four A + and four C+ presentations for group super generalization blocking and eight A+ presentations for group superblocking, where + represents the US). For these two groups the session length was doubled in order to keep trial spacing constant across groups. The onsets of the CS for groups blocking, blocking control, pseudoblocking and pseudoblocking control occurred 15, 25, 45, and 55 min into each session on Days 6 and 8, and 20, 30, 45 and 55 min into each session on Day 7. For groups super generalization blocking and superblocking, the onsets of the CS occurred 15, 25, 45, 55, 65, 80, 90, and 118 min into each session on Days 6 and 8, and 10, 25, 45, 60, 85, 100, and 115 min into each session on Day 7.

On Day 9 all groups received four reinforced presentations of their respective compound or elemental stimuli in a 1-hr session. Compounded cues were presented simultaneously. The onsets of the CS occurred 10, 25, 45, and 58 min into each session.

Reacclimation: On Days 10–12, all subjects were reacclimated to the variable-interval 20-s schedule during daily 1-hr sessions. This was done to reestablish baseline bar pressing, which may have been disrupted by the footshocks. No nominal stimuli were presented during these sessions.

Test: On Days 13 and 14 testing was conducted. During testing, suppression of the baseline response during presentation of the CS was assessed. The duration of each test session was 30 min. Each subject received four nonreinforced 30-s presentations of the CS each day with an intertrial interval of 5 min. A suppression ratio was calculated by dividing the sum of the number of bar presses exhibited during the CS on all eight CS test presentations (*d*) by the sum of the number of bar presses during the eight 30-s intervals prior to the CS onsets (*b*) and the number of bar presses during the CS (*d*), so the suppression ratio was equal to $d/(d + b)$. Thus, a suppression ratio of .5 indicates no suppression, and a ratio of 0 indicates complete suppression.

Results and discussion

To assure that baseline bar pressing did not appreciably differ across groups, an initial one-way analysis of variance (ANOVA) was conducted on bar press rate during the eight 30-s intervals prior to the CS onsets on the two test days. The mean number of bar presses per minute calculated over all eight 30-s pre-CS windows prior to the eight test trials was 12.9 for group blocking, 9.6 for group blocking control, 15.2 for group pseudoblocking, 13.5 for group pseudoblocking control, 15.4 for group super generalization blocking, and 13.0 for group superblocking, $p > .10$. Thus, no appreciable differences in baseline bar pressing were evident.

The central results of Experiment 1 are depicted in Figure 1. Plotted in this figure are the mean suppression ratios (±*SEM*) for each group over the eight test trials (four on the first day of testing and four on the second day of testing). This was done to equate our testing procedure with that of Blaser et al. (2006) to the fullest extent possible. The data passed both a normality test and an equal-variance test (i.e., *p*s > .05). An alpha level of .05 was adopted for all statistical analyses.

A one-way ANOVA conducted on the suppression ratios revealed that training had a significant effect, $F(5, 66) = 34.82$, $p < .001$; power with $\alpha = .05$ was 1. Pairwise comparisons performed using the LSD Fisher post hoc test revealed a conventional blocking effect (blocking vs. blocking control), $p < .001$, but more important there was no significant pseudoblocking effect (pseudoblocking vs. pseudoblocking control), $p = .72$. Thus, this experiment stands as the first report of conventional blocking that included a control demonstrating that the observed blocking was not an artifact of pseudoblocking. In addition, no differences were observed between the different blocking groups, with $p = .91$ for the blocking versus super generalization blocking comparison, $p = .22$ for the blocking versus superblocking comparison, and $p = .18$ for the superblocking versus super generalization blocking comparison. Thus, there was no evidence that training of two independent nontarget excitors produced appreciably more generalization to the target CS than did training of one nontarget excitor. In contrast, all three blocking groups were significantly different from the blocking control group, ps < .05.

These results indicate that we were able to obtain a blocking effect even when we controlled for potential differences in stimulus generalization. If differential generalization had been appreciable in our rat preparation, more fear to the blocked stimulus X should have been observed during testing in the super generalization blocking group than in the blocking group because X could receive generalized fear from the two excitors A and C in the super generalization blocking group, but only from Excitor A in the blocking group. It could be argued that the problem with this comparison is that the subjects in the super generalization blocking group received more shocks than the subjects in the blocking group, and that this

could have a bearing upon the amount of generalization. However, this argument would not account for the absence of any differences between the superblocking group and the super generalization blocking group as these groups received the same number of shocks. Here again, the generalization account predicts more fear in the super generalization blocking group, but if anything a nonsignificant tendency toward more fear was observed in the superblocking group.

Our other experimental objective was to obtain the pseudoblocking effect while using an analogue of our blocking control procedure. This failed as we were not able to reproduce the pseudoblocking effect that was observed by Blaser et al. (2006). However, it is not reasonable to dismiss the pseudoblocking effect because we did not use the same control condition as that used by Blaser et al. Therefore, one objective of Experiment 2 was to reproduce the pseudoblocking effect obtained by Blaser et al. using an analogue of their control condition.

EXPERIMENT 2

The first aim of Experiment 2 was to reproduce the pseudoblocking effect that Blaser et al. (2006) obtained with honeybees by implementing their control procedure in our bar press suppression preparation. At the same time, we reexamined the experimental protocol used by Blaser et al. with honeybees in order to replicate the conditions used by them as closely as possible. In the experimental design used by Blaser et al., the bees in their pseudoblocking group were exposed during Phases 1 and 2 to a feeder, with the feeder being a container holding a sugar solution that was accessible to the bees. This feeder was marked with odours, which acted as the experimental cues. In comparison, their pseudoblocking control group (named forward control in Blaser et al.) was presented with an unscented feeder containing a sugar solution in Phase 1. This was followed by the presentation of a scented feeder containing a sugar solution in Phase 2. At test, both the pseudoblocking and the pseudoblocking control groups were presented with the same feeder, but this time the feeder was marked using a novel odour.

Blaser et al. (2006) claimed that the feeder was treated as the training context. If this is correct, the pseudoblocking and the pseudoblocking control groups in our Experiment 2 (see Table 3) should have been equivalent to the one used by Blaser et al., thereby permitting observation of the pseudoblocking effect. However, a honeybee feeder could be viewed as conceptually equivalent to a flower because it is present for a relatively short period of time compared to a conventional context. Consequently it could be considered a punctate cue rather than a context because it is experienced by the bees for a short amount of time. Such a conceptual shift is quite important because by definition a context is of very low salience and so can be ignored in Blaser et al.'s experimental design. In contrast, a punctate cue typically has a relatively higher salience than a context and consequently cannot be ignored when analysing the experimental design of Blaser et al. As can be seen in Table 3, B, which is our punctate analogue of Blaser et al.'s feeder, is conditioned alone during Phase 1 in group pseudoblocking punctate control, whereas it is subject to overshadowing by A in group pseudoblocking punctate. This should give B more control over behaviour at test in group pseudoblocking punctate control than group pseudoblocking punctate given that testing is on a BX compound with X never having been reinforced.

In Experiment 2 the pseudoblocking and the pseudoblocking control groups were included to determine whether we could obtain a pseudoblocking effect in our bar press preparation using a control group modelled after that of Blaser et al. (2006)—that is, unsignalled USs were given in Phase 1; treatment of these groups was designed based on Blaser et al.'s assumption that the feeder served as a context of low salience. The treatments of the pseudoblocking punctate and pseudoblocking punctate control groups were designed as analogues to Blaser et al. assuming

that their feeder served as a punctate cue. This was achieved by having CS B present during Phases 1 and 2 as well as during testing. If we were to accept the punctate cue interpretation of the role of the feeder in Blaser et al., the pseudoblocking punctate and pseudoblocking punctate control groups in our Experiment 2 should have behaved equivalently to the pseudoblocking and forward control groups of honeybees in Blaser et al. Finally, the blocking and the blocking control groups were intended to see whether the addition of a novel stimulus (B), in compound with the target stimulus (X), at test would alter the conventional blocking effect.

Method

Subjects—The subjects were 36 male (290–375 g) and 36 female (190–260 g) experimentally naive, Sprague-Dawley descended rats obtained from our own breeding colony. Subjects were randomly assigned to one of six groups (*ns* = 12), counterbalanced within groups for sex. Subjects were housed and water deprived in the same manner as in Experiment 1.

Apparatus—The same apparatus was used in this experiment as in Experiment 1. The C stimulus was a 10-s flashing light (0.25 s on, 0.25 s off), 100-W bulb (nominal at 120 VAC) driven at 50 V. Cues A, B, and X were counterbalanced 10-s auditory stimuli consisting of a white noise 6 dB (C-scale) above background, a complex tone (500 and 520 Hz) 6 dB (C-scale) above background, and a 6-Hz click train 4 dB (C-scale) above background. The US was a 0.5-s, 0.7-mA footshock.

Procedure

Acclimation, shaping, and preexposure: On Days 1–5, all subjects were shaped to bar press and acclimated to the experimental context as described in Experiment 1. Additionally, to minimize unconditioned suppression at test, all subjects were exposed to test cues to which they would otherwise not be exposed until testing. Importantly, all critical comparisons were to be with pairs of groups receiving the same type of preexposure treatment.

Phase 1: On Days 6–9, all groups received four presentations of their respective CSs immediately followed by the US during 1-hr sessions (see Table 3). Onsets of the CS occurred 10, 25, 45, and 55 min into each daily session on Days 6 and 9, and 20, 30, 45, and 55 min into each daily session on Days 7 and 8. In the pseudoblocking punctate group, Cues A and B were coterminous.

Phase 2: On Day 10, all groups received four reinforced presentations of their respective CSs in a 1-hr session (see Table 3). As in Phase 1, compounded cues were coterminous. Onsets of CSs occurred 20, 30, 45, and 55 min into each daily session.

Reacclimation: During Days 11–13 all subjects were reacclimated to the variable-interval 20-s schedule in daily 1-hour sessions.

Test: During Days 14 and 15, all subjects were tested with stimulus X (groups pseudoblocking and pseudoblocking control), or the compound stimulus BX (groups blocking, blocking control, pseudoblocking punctate, and pseudoblocking punctate control). The test procedure was the same as that described for Experiment 1. As in Phase 1, compounded cues were coterminous.

Results and discussion

To assure that baseline bar pressing did not appreciably differ across groups, an initial oneway ANOVA was conducted on bar press rate during the eight 30-s intervals prior to the CS onsets.

The mean number of bar presses per minute was 17.2 for group blocking, 10.8 for group blocking control, 11.7 for group pseudoblocking punctate, 11.4 for group pseudoblocking punctate control, 11.0 for group pseudoblocking, and 11.0 for group pseudoblocking control, $p > .10$. Thus, no appreciable differences in baseline bar pressing were evident.

The central results of Experiment 2 are depicted in Figure 2. This figure illustrates the mean suppression ratio ($\pm SEM$) for each group. The data passed a normality test and an equal-variance test (i.e., ps $> .05$).

A one-way ANOVA conducted on the suppression ratios revealed that training had a significant effect, $F(5, 66) = 3.48$, $p < .01$; power of the performed test with $\alpha = .05$ was .746. Planned comparisons were performed to assess pairwise comparisons of interest. The error terms for the planned comparisons were unpooled because the power of the ANOVA was less than .8, and that, in addition to the near failure of the equal variance test, suggested that the use of the pooled variance could be detrimental to the power of the pairwise comparisons. Furthermore, because we were interested in only three comparisons, we decided against using the LSD Fisher test for multiple pairwise comparisons. Instead, degrees of freedom were adjusted to compensate for the number of comparisons performed. No significant differences were detected between the pseudoblocking group and the pseudoblocking control group, $p = .81$, which replicates Experiment 1 by manifesting no pseudoblocking effect when the experimental context is used as the analogue of Blaser et al. (2006) feeder. Notably, in the present experiment we used Blaser et al.'s control treatment. However, the pseudoblocking punctate group and the pseudoblocking punctate control group were found to differ, $F(1, 20.9) = 5.09$, $p < .05$, which replicates Blaser et al.'s pseudoblocking effect when a punctate stimulus is used as an analogue to their feeder. Additionally, the blocking phenomenon (group blocking vs. group blocking control) was still observed despite the addition of a novel stimulus at test, $F(1, 21.9) = 5.56$, $p < .05$. Thus, compounding target CS X with B did not attenuate the basic blocking effect.

Based on these results, we conclude that the pseudoblocking phenomenon as described by Blaser et al. (2006) was not observed in our rat preparation. However, by changing the assumption made by Blaser et al. concerning the experimental status of the feeder from that of a context to a punctate cue, the pseudoblocking effect did emerge. Nevertheless, in its present form with the feeder modelled by a punctate cue the pseudoblocking effect is not a challenge for any of the contemporary learning theories.

GENERAL DISCUSSION

The central finding of these experiments is that blocking occurs even when compared to a pseudoblocking control group. In our situation, pseudoblocking did not occur unless we treated the analogue of Blaser et al.'s (2006) honey bee feeder as a punctate cue, which precludes a common account of pseudoblocking and conventional blocking. When we proceeded on the basis of Blaser et al.'s assumption that their bee feeder functioned as a context, we were not able to reproduce the pseudoblocking effect as reported by Blaser et al. using either an analogue of our usual blocking control procedure (Experiment 1) or a blocking control procedure modelled after that of Blaser et al. (Experiment 2). Why the pseudoblocking effect was not observed under these conditions is unclear, but the difference in species—rats as opposed to bees—is one possible candidate. However, when we modelled the role of the feeder in their procedure as a punctate cue rather than a context (group pseudoblocking punctate), we were able to reproduce their empirical result of pseudoblocking. This suggests that our failure to observe pseudoblocking in rats when we modelled the bee feeder as a context was not due to the difference in species used between Blaser et al. and the present experiments, but instead was due to the initial error of regarding the feeder as a context.

Importantly, when the feeder is conceptualized as a punctate cue, the pseudoblocking effect can readily be explained by any learning theory that can account for overshadowing of the experimental context by Stimulus A. For example, in the framework of the comparator hypothesis (Miller & Matzel, 1988; Stout & Miller, 2007), the response by groups pseudoblocking punctate and pseudoblocking punctate control of Experiment 2 to the compound BX should be equal to the sum of the response potential of its elements. In this case, there should be little or no response component due to stimulus X because X was only paired with the context and not with the US. Consequently the response to the compound BX should depend only upon the response potential of Stimulus B. Using the equations of Stout and Miller (2007), the response to Stimulus B in the pseudoblocking punctate and the pseudoblocking punctate control groups is $R_B = $ Link $1 - k3$(Link $2 \times$ Link 3), where $k3$ is the comparator parameter. If we assume that Stimuli A and B had equal salience, the strength of the A–US association (Link 3) should have been equal to the strength of the B–US association (Link 1) due to the extended training of the compound AB in both phases for the pseudoblocking punctate group. Moreover, Link 2 should have been strong due to consistent A–B pairing in both phases. In contrast, in the pseudoblocking punctate control, both the A–US (Link 3) and A – B (Link 2) associations should have been weaker due to the absence of A during Phase 1. Consequently stronger responding to BX would be expected in group pseudoblocking punctate control than in group pseudoblocking punctate. This is exactly what was observed.

Pearce's configural theory (1987, 2002) is another model that can explain psuedoblocking when the feeder is regarded as a punctate cue. It too does so by predicting that A will overshadow the context (B) in group pseudoblocking punctate. If we posit asymptotic performance after Phase 1 in the pseudoblocking punctate control group, configural theory predicts that $E_B = \lambda$, where E_B is the associative strength of B. In Phase 2, the compound AB should have activated the configural unit for B to 0.5λ, so the configural unit AB could only increase to 0.5λ in this phase, and consequently $E_{AB}^{max} = 0.5\lambda$. However, for the pseudoblocking punctate group the configural unit for the compound AB after Phase 1 and 2 should have been $E_{AB} = \lambda$. At testing both groups were presented with the compound BX. For the pseudoblocking punctate group, $E_{BX} = {}_{BX}S_{AB} \times V_{AB}$, with ${}_{BX}S_{AB} = (N_C/N_{BX}) \times (N_c/N_{AB}) = 0.5 \times 0.5 = 0.25$, so $E_{BX} = 0.25\lambda$. In contrast, for the pseudoblocking punctate control group, $E_{BX} = ({}_{BX}S_{AB} \times V_{AB}) + ({}_{BX}S_B \times V_B)$, with $B_{AB}^{max} = (N_c/N_{BX}) \times (N_c/N_{AB}) = 0.25$ and ${}_{BX}S_B = (N_C/N_{BX}) \times (N_C/N_B) = 0.5 \times 1 = 0.5$, and consequently, $E_{BX} = (0.25 \times V_{AB}) + (0.5 \times V_B) = 0.625\lambda$. Thus, the response of the pseudoblocking punctate control group ($E_{BX} = 0.625\lambda$) should have been greater than the response of the pseudoblocking punctate group ($E_{BX} = 0.25\lambda$), which is consistent with what was observed—that is, the pseudoblocking effect in group pseudoblocking punctate. However, it is interesting to note that the ordinal prediction still stands, even if $V_{AB} = 0$ after Phase 2 training for the pseudoblocking punctate control group.

The simplest theoretical account of pseudoblocking when the context is regarded as a punctate cue is probably offered by the Rescorla–Wagner model (Rescorla & Wagner, 1972). If we posit equal salience for Stimulus A and Stimulus B and asymptotic performance after Phase 1 in the pseudoblocking punctate control group, we have $V_B = \lambda$. Therefore, after Phase 2, $V_{AB} = V_B + V_A$, $V_B = \lambda$, and $V_A = 0$. In the pseudoblocking punctate group after Phases 1 and 2, $V_{AB} = \lambda$, and, because we are postulating equal salience for A and B, $V_A = V_B = 0.5\lambda$. At test, both groups were presented with the compound stimulus BX, and since X was never trained, $V_X = 0$. Thus, for the pseudoblocking punctate group, $V_{BX} = V_B + V_X = 0.5\lambda$, whereas the pseudoblocking punctate control group, $V_{BX} = V_B + V_X = \lambda$. Consequently, the Rescorla–Wagner model also predicts stronger stimulus control of behaviour in the pseudoblocking punctate control group than in the pseudoblocking punctate group.

We conclude that the so-called pseudoblocking effect of Blaser et al. (2006) can be explained by most traditional theories of learning in terms of associative overshadowing of B by A.

Moreover, it is observed only under conditions that involve more than the omission of the target stimulus in Phase 2 of a conventional blocking preparation; it requires an additional stimulus, such as B, to be present during Phases 1 and 2 as well as test. Consequently, the pseudoblocking effect neither provides nor compels an alternative account of the basic blocking phenomenon. Since the pseudoblocking effect was observed in our preparation only when a punctate cue was used as a surrogate feeder, we conclude that the observation of the pseudoblocking effect was probably due to Blaser et al.'s bee feeder functioning as a punctate cue that was overshadowed by A during both Phases 1 and 2 in Blaser et al.'s pseudoblocking group (see Table 1) and our pseudoblocking punctate group (see Table 3). Although this account explains the pseudoblocking phenomenon, unlike the generalization account of pseudoblocking, it is unable to explain conventional blocking. Thus, it appears that Kamin's (1969) blocking effect remains a real phenomenon, distinct from the mechanism that accounts for pseudoblocking, which must be addressed by all models of associative learning. In the light of our present work, the results obtained by Blaser et al. do not appear to challenge accounts of blocking provided by current learning theories.

Although our experiments have demonstrated that generalization from A and B in the pseudoblocking control condition of Experiment 1 and generalization from A and the context in the pseudoblocking control condition of Experiment 2 do not provide an adequate account of blocking (or pseudoblocking) with the present parameters, surely differential generalization is a potential factor that should be considered in any study of blocking. However, it is not something for which prior researchers have ordinarily controlled. Probably, this has been because past researchers have typically used physical stimuli for X and A and the context (B) that minimized generalization to X. Certainly that was the case in our preparation. Moreover, contrary to the assertion of Blaser et al. (2006), their pseudoblocking effect is not beyond the realm of conventional associative models. When one recognizes that their bee feeder probably served as a punctate stimulus rather than a context, so-called pseudoblocking is seen to be no more than a consequence of the well-established phenomenon of overshadowing.

Blaser et al. (2006) are correct in warning researchers of the potential effect of differential generalization to X, but we have here demonstrated that, at least in our preparation, blocking occurs even when control groups show that appreciable generalization has not occurred. More important than our providing a conventional account of Blaser et al.'s (2006) pseudoblocking effect, in both of the present experiments we obtained blocking while simultaneously controlling for the first time for differential generalization between the blocking and blocking control groups.

Acknowledgements

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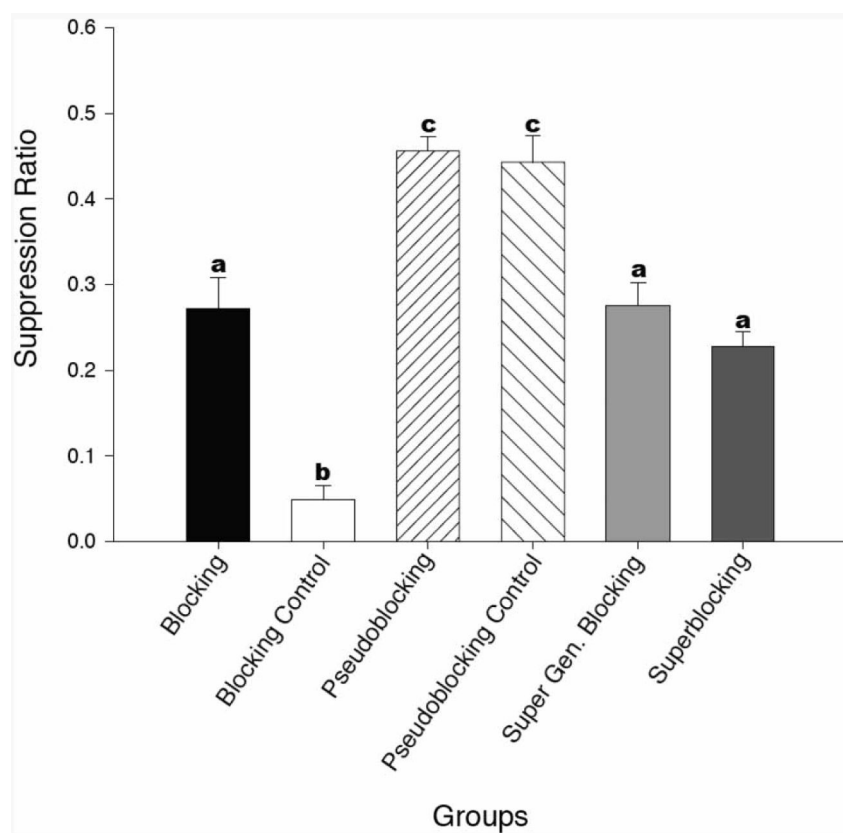
Figure 1.
Results of Experiment 1. Group means of suppression ratios ± SEM. *Different letters indicate significant differences*.
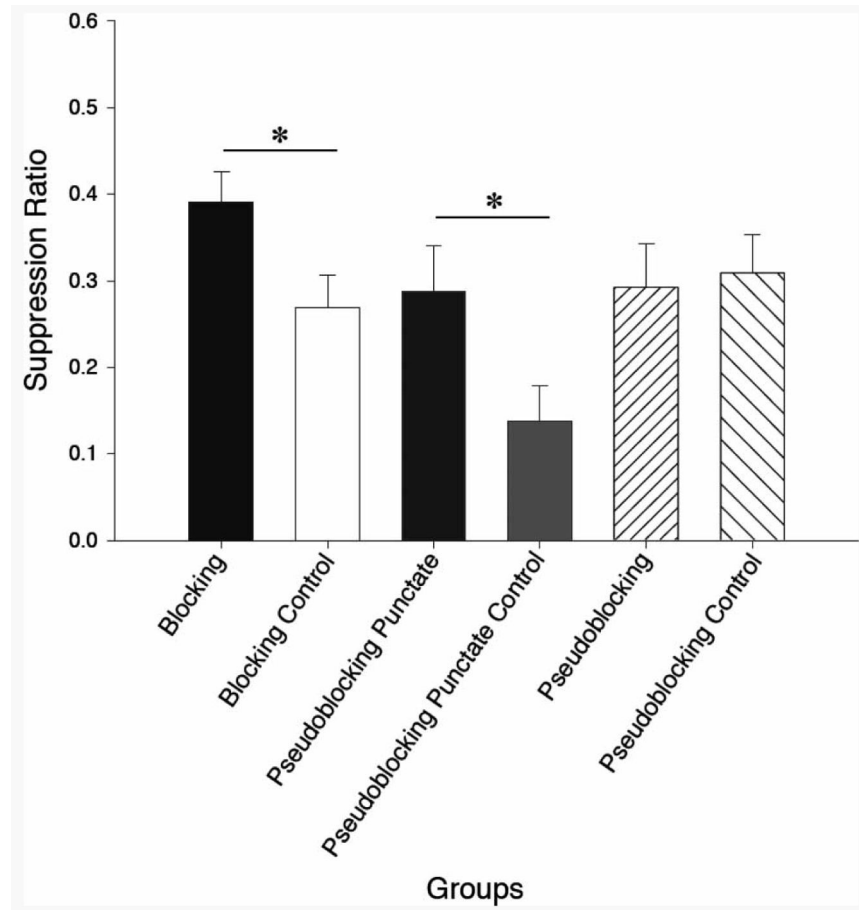
Figure 2.
Results of Experiment 2. Group means of suppression ratio ± SEM. Significant differences of interest are indicated by*.

Table 1

Experimental design for Blaser et al.'s (2006) Experiment 1

Group name	Phase 1	Phase 2	Test	Observed
Pseudoblocking	A +	A +	X	*cr*
Forward control	+	A +	X	CR
Backward control	A +	+	X	CR

Note: All phases and tests took place in the same context, and therefore context has been ignored. A and X represent different odour cues (X was never trained). + indicates reinforcement. CR and cr denote the observed strong and weak levels of conditioned responding, respectively.

Table 2

Experimental design for Experiment 1

Group name	Pre-exp	Phase 1	Phase 2	Test	Pred. 1	Pred. 2
Blocking	2 X	12 A +	4 AX+	X	Cr	Cr
Blocking control	2 X	12 C +	4 AX+	X	CR	CR
Pseudoblocking	2 X	12 A +	4 A+	X	cr	—
Pseudoblocking control	2 X	12 C +	4 A+	X	Cr	—
Super generalization	2 X	12 C +/12 A +	4 AX+	X	CR	Cr
Superblocking	2 X	12 A +/12 A +	4 AX+	X	Cr	cr

Note: A and C were counterbalanced auditory cues (complex tone and white noise), and X was a click train. + indicates reinforcement. Preexposure (Pre-exp) to X was administered in order to avoid unconditioned fear at testing. CR, Cr, and cr denote the expected level of the conditioned response from strong to medium to weak, respectively. The columns Pred. 1 and Pred. 2 contain predictions based on the work of Blaser et al. (2006; Pred. 1) and predictions based on accounts of blocking from all contemporary models of associative learning (Pred. 2; see General Discussion).

Table 3

Experimental design for Experiment 2

Group name	Pre-exp	Phase 1	Phase 2	Test	Prediction
Blocking	2 B	12 A +	4 AX+	BX	cr
Blocking control	2 B	12 C +	4 AX+	BX	Cr
Pseudoblocking punctate	2 X	12 AB +	4 AB+	BX	Cr
Pseudoblocking punctate control	2 X	12 B +	4 AB+	BX	CR
Pseudoblocking	2 X	12 A +	4 A+	X	—
Pseudoblocking control	2 X	12 +	4 A+	X	—

Note: A, B, and X were counterbalanced auditory cues, and C was a flashing light. + indicates reinforcement. Preexposure (Pre-exp) to X or B was administered in order to avoid unconditioned fear at testing. In the pseudoblocking and pseudoblocking punctate groups, B modelled Blaser et al.'s bee feeder. CR, Cr, and cr denote the expected level of the conditioned response from strong to medium to weak, respectively, based on all contemporary associative theories.