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Assessing the blocking of occasion setting

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ABSTRACT

An occasion setter (OS) is a stimulus or context with the capacity to disambiguate an ambiguous conditioned stimulus (CS). Previous research has shown that OSs share some features with regular Pavlovian CSs. Amongst them, research has shown that OSs are subject to blocking; that is, a new OS exerts reduced behavioral control after training in compound with a previously established OS. Of additional interest, in Pavlovian blocking, it has been reported that a blocked CS comes to elicit conditioned responding after the extinction of the blocking CS. This is an example of retrospective revaluation, a family of phenomena in which the response to a specific stimulus is modified by training a related cue.

Here, three experiments sought to extend the analogies between OS and Pavlovian conditioning by examining the blocking of OSs and its retrospective revaluation. In all experiments, an OS was established by pairing a CS with food in the presence of the OS, but not in its absence (i.e., positive OS). Blocking was then trained by presenting the OS in compound with a novel OS. Experiment 1 showed blocking of the second OS, but direct exposure to the blocking OS did not enhance responding to the second OS. Experiment 2 replicated the blocking effect but subsequent training of the blocking OS with a reversed contingency showed no retrospective revaluation. Experiment 3 examined whether blocking of the OS occurred with a novel CS during the compound phase. In this experiment blocking was again observed, but only when subjects were tested with the original CS. These results are discussed focusing on the underlying links at work in occasion setting.

1. Introduction

In Pavlovian conditioning, a stimulus is repeatedly paired with an unconditioned stimulus (US) that elicits a response without need of training. After this experience, the stimulus (now a conditioned stimulus, CS) comes to elicit responding (conditioned responses, CR) due to its association with the US (Pavlov, 1927). Within the associative framework, an occasion setter (OS) refers to the potential of a cue or context to modulate or facilitate responding to a partially reinforced CS. That is, the OS sets the occasion for responding (or not responding) to the CS (eg, Holland, 1983; Miller and Oberling, 1998). Recently, there has been a surge of interest in OS research (e.g., Leising and Bonardi, 2017; Trask et al., 2017) and modeling (e.g.,Vogel et al., 2017).

Behavioral phenomena observed in occasion setting seem to parallel many phenomena reported in standard Pavlovian excitatory conditioning (e.g., Miller and Oberling, 1998). Of special interest for this study is the blocking effect, which has been found in both occasion setting and Pavlovian conditioning. In standard Pavlovian conditioning, blocking (Kamin, 1969) refers to the impairment in the control of behavior by a reinforced CS (X) when this CS has been trained in compound with a previously reinforced cue (i.e., A+ then AX+). Similarly, a couple of reports have shown that a potential OS does not develop modulatory properties when it has been trained in compound with an established OS, that is, occasion setting can be blocked (Bonardi, 1991; Swartzentruber, 1991). This is consistent with several other reports of analogies between occasion setting and excitation in phenomena such as overshadowing (Cole et al., 1997), extinction (Rescorla, 1986b), and latent inhibition (Oberling et al., 1999), supporting the idea that occasion setting and Pavlovian conditioning have parallels in what and how they control responding. However, it would be premature to assume that the evidence we hold at this moment is enough to sustain that the mechanism is unequivocally the same.

The goal of the present study was threefold. First, we aimed to assess the blocking of occasion setting. Previous findings (Bonardi, 1991, Experiment 1) on blocking of occasion setting in between-subjects designs have used a control group where one putative OS of the compound was previously trained with uncorrelated presentations of the CS and the US. The problem with this arrangement is that the low behavioral control produced by the CS in the control group could be explained not necessarily by blocking, but by a CS preexposure effect

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(Lubow and Moore, 1959) or by learned irrelevance (Baker et al., 2003). We used a different control group that produces ambiguity of the CS in the first phase (see below) and we also presented novel cues in the compound phase to prevent other confounding processes (e.g., CS preexposure). We also differentiate from Swartzentruber (1991) in that we compare the blocking of stimuli of the same characteristics and modality.

Our second goal was to assess the retrospective revaluation (RR) of blocking of occasion setting. RR refers to a change on the effect that a trained cue produced on behavior (typically a CS), that occurs after giving further training to a different cue. In Pavlovian conditioning, Kaufman and Bolles (1981) first reported RR in an overshadowing experiment with rats (see also Matzel et al., 1985). A noise-light compound was paired with an electric shock in one group. At test with the noise alone, subjects showed less freezing compared to another group conditioned with only the noise (i.e., overshadowing). The group with compound training received then extinction of the light, after which an increase in conditioned responding to the noise alone, even though they did not have any additional experience with the sound. RR of Pavlovian blocking, in which there is an increment in responding to the blocked cue after extinction of the blocking cue, has been reported both in human causal learning (Dickinson and Burke, 1996; Dickinson et al., 1984; Dopson et al., 2009; Shanks, 1985) and in fear conditioning (Blaisdell et al., 1999). In a similar manner, blocking of occasion setting may be retrospectively reevaluated if after blocking training, one element of the OS compound is manipulated to reduce its OS potential, that is, a blocked OS can be "unblocked", meaning that it can recover its capacity to disambiguate behavioral control by a CS.

Finally, our third objective was to assess whether blocking of OS also occurs in an OS transfer procedure. Transference is the ability of an OS to disambiguate other CSs that were previously disambiguated by other OSs (Holland, 1989). In blocking of occasion setting, transfer can occur when a new CS is used in the compound phase, and when the blocked OS is tested with the original CS. We assessed both in Experiment 3 (see below).

In summary, Experiment 1 aimed to replicate the effect of blocking of occasion setting, but using a different control condition compared to previous studies (e.g., Bonardi, 1991; Swartzentruber, 1991). Experiment 2 intended to examine RR of blocking with a different procedure compared to Experiment 1. Finally, Experiment 3 examined blocking of occasion setting in an OS transfer procedure.

2. Experiment 1

This experiment assessed the blocking of occasion setting by training a new OS in compound with a previously established OS (see Table 1 for the experimental design). Previous reports (Bonardi, 1991) of blocking of occasion setting first trained a feature positive stimulus with an ambiguous CS. We trained this feature positive OS in a "local context" form in three different groups, Block-Ext, Blocking, and Control. The OS (Y for Block-Ext and Blocking, and W for Control Group) was a stimulus of 4.5 min duration, presented five times in each session, and during each of these trials a CS (A) was presented six times. Each of the presentations of A during the OS lasted 5 s and co-terminated with the delivery of a food pellet. In addition, A was also presented six times in the absence of the OS, that is, during the inter-trial interval (ITI), but without the US. In the compound phase for groups Block-Ext and Blocking, a second stimulus (X) was presented in compound with the established OS, receiving a similar training as in the previous phase. In the Control group, X was presented in compound with a novel cue (Y). X was then tested with the CS A in all groups. Higher responses to the XA compound in the Control Group would be indicative of blocking of OS. After this test, the group Block-Ext received additional presentations of Y and the CS A, but no US was delivered, i.e., extinction (e.g., Franssen et al., 2017). Finally, RR was assessed by testing the XA compound in the groups Block-Ext and Blocking. Higher responses to the compound in the Block-Ext Group compared to the Blocking Group would be indicative of RR.

2.1. Subjects

Subjects were 36 male Sprague Dawley descended young adult rats. Animals were single housed in plastic cages in a vivarium and kept in a 16/8 h. light/dark cycle. Before the start of the experiment, subjects were deprived of food until they reached 85% of their free-feeding weight, and then maintained at this weight level until the end of the experiment. Animals were randomly assigned to one of three conditions ($n = 12$): Block-Ext Group, Blocking Group and Control Group. All procedures were approved by the ethics committee of the Science College at the University of Chile.

2.2. Apparatus

Six experimental chambers (Med Associates Inc.) were used for these experiments. The dimensions of each chamber were 32 × 25 × 26 cm. The two sidewalls and the ceiling were made from clear Plexiglas, and the two end walls were made of stainless steel, while the floor was composed by steel bars of 0.5 cm of diameter separated by 1.2 cm. In one of the end walls there was a feeder and two 30 v 4 w light bulbs. The feeder was located on the bottom right side of the wall, one of the bulbs on the bottom left and the other on the top right of the wall (Bottom Light and Top Light). On the center of the opposite wall there was a third light bulb with the same characteristics as the others (House Light), which could emit a flashing light at a .25 s on .25 s off schedule. One speaker was placed on each of the two end walls, which provided either a 1000 Hz tone or a white noise 6 dB above environment noise (measured at 70 db) in the A scale.

CS A was either the tone or the white noise, counterbalanced lasting 5 s. The Bottom and Top Lights lasting 4.5 min were used as OSs Y and X, also counterbalanced. The Houselight flashing at 4 Hz was used as OS W. The US was the delivery of a 45-mg sucrose pellet (Bioserv).

2.3. Procedure

2.3.1. Acclimation

On Day 1, all animals received a 30-min magazine training session. Pellets were delivered according to a 60-sec variable time schedule. On Day 2, the subjects were pre-exposed to the stimuli that were to be used later as OSs and CSs in a 20-min session, receiving one presentations of each OS, and two presentations of each CS alone. The order of

Table 1
Experiment 1 Design.

Group	Training	Compound	Blocking Test	CR	Extinction	RR Test	CR
Block-Ext	Y → A+/A−	YX → A+ /A−	X → A−	cr	Y → A−	X → A−	Cr
Blocking	Y → A+/A−			cr	Context	X → A−	cr
Control	W → A+/A−			CR			

Note. W, X and Y are light stimuli in different places of the chamber, X and Y were counterbalanced. A was a 1000 Hz tone or a white noise of 8 dB over background noise, counterbalanced. + and − denote delivery or absence of the US, respectively. "cr", "Cr" and "CR" indicate expected response levels for each group, from low to high respectively.

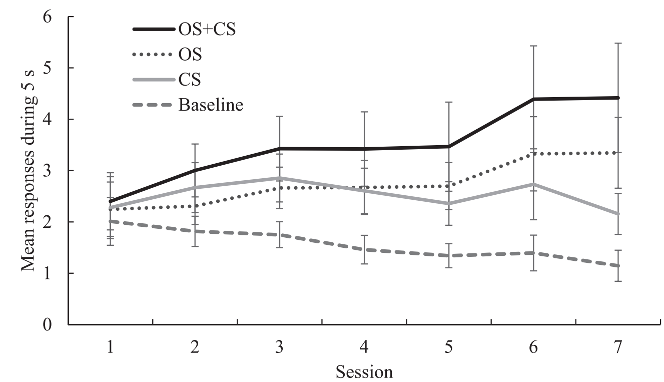

Fig. 1. Acquisition in Experiment 1.
Each line represents a different measure. OS + CS represents responding to the CS during the OS. CS represents responding to the CS during the ITI. OS represents responding during the 5 s prior to the CS onset during the OS. Baseline represents responding to the 5 s prior to the CS onset during the ITI. All groups are collapsed. Bars represent 95% CI for each session.

presentation was: Houselight, white noise, tone, white noise, tone, Top Light, Bottom Light.

2.3.2. Training

On days 3–9, all animals received one daily 45-min session. Subjects in groups Block-Ext and Blocking received 5 daily presentations of the OS Y. The session began with an immediate presentation of Y. The CS A was then presented 6 times during the presentation of Y, each of them co-terminating with the presentation of a 45 mg pellet (i.e., Y → A+). Then, a 4.5 m interval started during which 6 presentations of CS A occurred. These presentations were non-reinforced (i.e., A−). The moment in which A was presented both within Y and out of Y was randomly selected from 6 possible intervals: 30, 31, 35, 43, 47 and 51-s. Subjects in the Control Group received the same training, but using OS W instead of OS Y.

2.3.3. Compound training

On days 10–12, all animals received one daily 45-min session. In these sessions Y and X were trained in compound as OSs for the reinforcement of A, with simultaneous onset and offset of the OSs for all groups. All stimuli were presented in a similar manner to the previous phase.

2.3.4. Blocking test

On Day 13, all subjects received two presentations of X with six presentations of A in each of them with no reinforcement in an 18-min session. Feature onset occurred at 3 and 12 min into session. CSs were programed to occur during OS X as described in Training.

2.3.5. Extinction

On days 14–16, subjects in Group Block-Ext received one daily 18-min session, in which Y → A was presented twice with no reinforcement, with a 6 min ITI. OS onset occurred at 3 and 13.5-min into the session. CSs were programmed to occur during Y as described in Training, with the difference that no pellet was delivered at the end of the CS. Animals in Group Blocking had 18 min of exposure to the experimental chamber, while subjects in Group Control remained in their home cages and did not received further treatment in the experiment.

2.3.6. RR test

On Day 17, Groups Block-Ext and Blocking received two presentations of X → A with no reinforcement in a similar way to the Blocking Test.

2.4. Results and discussion

In this experiment, we found blocking of X in groups Block-Ext and Blocking, compared to Group Control. CS A was then extinguished in the presence of OS Y in Group Block-Ext, with the intent to diminish the modulatory potential of OS Y. The results show that this manipulation did not produce an increase in responses to CS A during OS X in the RR test, but produced instead an even lower level of responses. The following statistics support these statements.

Magazine entries were measured during training in each of the 5 s CS presentations, and during the 5 s prior to the CS onset both during the presence or absence of the OS. This produced four different measures. Responses prior to and during the CS in the absence of the OS are defined as “Baseline” and “CS”, respectively. Responses made before the CS and during the CS in the presence of the OS are called “OS” and “OS + CS”, respectively. A mixed ANOVA was performed with Measure and Session as within-subject factors, and Group as a between-subject factor. The Session × Measure × Group interaction was not significant, $F(36, 522) = 0.3534$, $p > 0.05$, MSE = 0.616, $\eta_p^2 = 0.02$. More importantly, they revealed differences in responding as training progressed, shown by the Session × Measure interaction, $F(18, 522) = 10.53$, $p < .01$, $MSE = 0.62$, $\eta_p^2 = 0.27$. A planned comparison with the data of the last session showed that the OS + CS measure was significantly higher than the OS or CS measures, $F(1, 29) = 12.89$, $p < .01$, MSE = 4.09, $\eta_p^2 = 0.3$ (see Fig. 1).

In the Blocking Test, magazine entries were registered during the presentations of the OS + CS. Analyses were performed on the average responding rate during each of the two OS trials. Outliers were excluded from the analyses, defined as subjects over 1.5 inter-quartile range (3 subjects in Group Block-Ext, 2 in Group Blocking, and 1 in Group Control). A mixed ANOVA was performed, with Trial as within-subject factor, and Group as between-subject factor. The analysis showed no Trial × Group interaction, $F(2, 27) = 2.8$, $p = 0.077$, $MSE = 0.82$, $\eta_p^2 = 0.17$, a significant effect of Trial, $F(1, 27) = 4.29$, $p < .05$, $MSE = 0.82$, $\eta_p^2 = 0.14$, and a significant effect of Group, $F(1, 27) = 5.15$, $p < .05$, $MSE = 1.84$, $\eta_p^2 = 0.27$ More importantly, planned comparisons confirmed that responding in the Blocking and Block-Ext groups did not differ ($p > .07$), and when data from these two groups was pooled, they responded less than the Control Group, indicative of blocking of occasion setting (see left side of Fig. 2), $F(1, 27) = 6.5$, $p = .016$, $MSE = 1.84$, $\eta_p^2 = 0.19$. This difference becomes marginal if outliers are not excluded.

Responses during the RR Test were registered in a similar manner as in the Blocking Test. Data from each test were averaged and analyzed in a mixed ANOVA with Test (Blocking, RR) as within-subjects factor, and Group as between-subjects factor. This analysis yielded a significant Test × Group interaction, $F(1, 17) = 14.07$, $p < .01$, $MSE = 0.49$, $\eta_p^2 = 0.45$. Visual inspection suggests that the source of this interaction

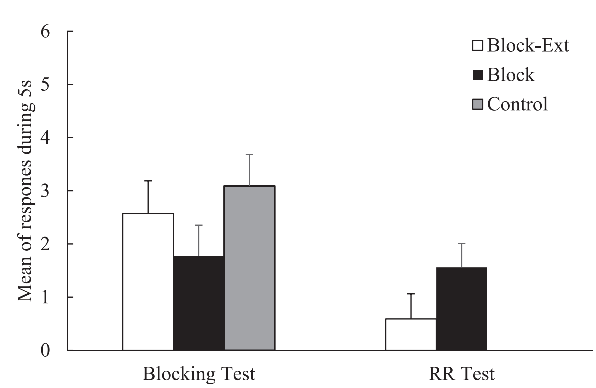

Fig. 2. Blocking and RR tests of Experiment 1.
Bars represent mean responses to the CS during the OS duration. Error bars represent 95% CI.

seemed to be the low responses of Group Block-Ext on the RR Test. This is opposite to the expected RR effect, which would have shown higher responses on the Block-Ext Group than the Blocking Group. A one-way ANOVA showed that the Block-Ext Group had significantly lower responses than the Blocking Group in the RR Test, $F(1, 17) = 6.1, p = .02$, $MSE = 0.6$, $\eta_p^2 = 0.26$. This effect is most likely due to the extinction procedure, which was designed to diminish the modulatory potential of OS Y. In that phase, both OS Y and CS A were presented without the reinforcer, thus extinguishing CS A. This procedure may have not been effective in extinguishing the modulatory potential of OS Y, and even if this procedure affected the potential of OS X to modulate CS A, responses to CS A may have remained low due only to its extinction. Experiment 2 aimed to avoid this situation by keeping CS A as an ambiguous excitatory CS, while diminishing the modulatory potential of OS Y.

3. Experiment 2

Experiment 1 showed blocking of OS. However, the procedure failed to produce retrospective revaluation of the blocked OS X after the extinction of the blocking OS Y. Experiment 2 tried a different approach to extinguish the modulatory properties of the OS, using a control procedure for occasion setting. In comparison to Experiment 1, the main modification was made in the extinction phase of Group Block-Ext, in which the OS Y was extinguished by reversing the contingency of reinforcement for A during Y, that is, by presenting A without reinforcement during Y, but reinforced during the ITI. Group Block was exposed to equal presentations of the CS but without any OS present. This reduces responding to the YA compound (e.g., Delamater et al., 2010). Additionally, Experiment 2 also included a different control procedure during the extinction phase.

To ensure that responding to the CS during the OS was not controlled solely by simple Pavlovian associative processes, OS W in the control group received extinction as a simple Pavlovian stimulus, i.e., in the absence of the CS. During an occasion setting training, the CS and the OS precede the US, and because of this, both can be associated with the US and gain excitatory properties. Several studies have shown that, while an OS can acquire Pavlovian properties, they seem to be independent from their modulatory properties (Holland, 1983, 1985; Rescorla, 1985, 1986a, 1986b, 1987; Ross, 1983; but see, Moore and Choi, 1998). For example, the modulatory potential of an OS is not affected by traditional extinction procedures (i.e., mere exposure of the OS alone; e.g., Holland, 1983), nor by delivering OS-US pairings before testing; e.g., Rescorla, 1985. If our extinction procedure does not abolish all modulatory control from the OS in a subsequent W → A test, then responding to the CS during the feature must be modulated by the OS. Based on the previous literature, we hypothesize that this treatment will reduce the modulatory potential of OS Y and cause a RR of OS X. A response recovery to CS A during OS X in a subsequent RR Test would be indicative of RR. A summary of the design is shown in Table 2.

3.1. Subjects and apparatus

Subjects were 36 male Sprague Dawley descended young adult rat housed in equal conditions to those described in Experiment 1. Animals were randomly assigned to one of three conditions ($ns = 12$). All stimuli, apparatus, and other conditions were identical to those used in the previous experiment.

3.2. Procedure

3.2.1. Acclimation, training, blocking and blocking test

On Days 1–2, all animals received the acclimation training. On Days 3–9, all subjects received one daily 45-min session of occasion setting training. On Days 10–12 all animals received compound training, and on Day 13, the Blocking Test was conducted. All procedures were carried out in the same way as Experiment 1.

3.2.2. Extinction

On Days 14–16, animals in Group Block-Ext received a daily 21 min session, in which the CS-US contingency in the presence and absence of the OS was inverted, relative to the Training phase. CS A presentations were reinforced in the absence of the OS Y, but not during the OS Y presentation. The OS Y onset occurred at 3 and 12 min into session. CS presentations were programed to occur as described in the Training phase of Experiment 1. For Group Blocking, CS A was reinforced as in Group Block-Ext, except that OS Y was never presented during this session. Importantly, and to assess the independence of occasion setting properties from Pavlovian properties, subjects in the Control Group received trials of OS W alone, without any CS or US presentations, in the same timing as the OS Y of the Block-Ext Group.

3.2.3. RR test

On Day 17, subjects of groups Blocking and Block-Ext received two presentations of X→A with no reinforcement as in Experiment 1. Subjects in Control Group received two presentations of W → A, with no reinforcement, presented in a similar way to the other tests.

3.3. Results and discussion

Experiment 2 showed that OS X was blocked in the Blocking and Block-Ext groups, compared to the Control Group, as in Experiment 1. During the RR Test, the control group showed that extinguishing OS W as a Pavlovian CS did not reduce its potential to modulate CS A, indicating independence of the occasion setting and Pavlovian properties of OS W. More central to the experiment, it also showed no evidence of RR of OS X, after OS Y was extinguished using a reverse contingency treatment (i.e., Y− > A− / A+). The following inferential analyses support these statements.

Responses during training were measured as in Experiment 1. The data of this phase was analyzed using a mixed ANOVA with the four Measures (Baseline, CS, OS, OS + CS), and seven Sessions as within-subject factors, and Group as a between-subjects factor. There was no Sessions × Measures × Group interaction, $F(18, 576) = 0.38, p > .05$, $MSE = 0.54$, $\eta_p^2 = 0.02$. Of more interest, it showed that the measures differentiated as sessions progressed, indicated by the Sessions × Measures interaction, $F(18, 576) = 10.19$, $p < .01$, $MSE = 0.54$, $\eta_p^2 = 0.24$ (see Fig. 3). A planned comparison showed that the OS + CS measures was higher than either the OS or the CS measures, in the last acquisition session, $F(1, 32) = 18.06$, $p < .01$,

Table 2
Experiment 2 design.

Group	Training	Compound	Blocking Test	CR	Extinction	RR Test	CR
Block-Ext	Y → A+/A−	YX→A+ /A−	X→A-	cr	Y → A−/ A+	X → A−	Cr
Blocking	Y → A+/A−			cr	A−/ A+	X → A−	cr
Control	W → A+/A−			CR	W	W → A− / A−	

Note. W, X and Y are light stimuli in different parts of the chamber. A was a 1000 Hz tone or white-noise of 8 dB over background noise, counterbalanced. + and − denote delivery or absence of the US, respectively. “cr”, “Cr” and “CR” indicate expected response levels for each group, from low to high, respectively.

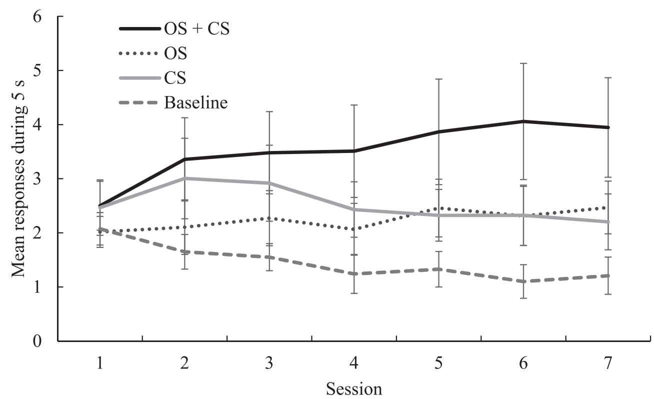

Fig. 3. Acqisition of Experiment 2.
Each line represents a different measure. OS + CS is responding to the CS during the OS duration. CS is responding to the CS during the OS ITI. OS is responding during the 5 s prior to the CS onset during the OS duration. Baseline is responding to the 5 s prior to the CS onset during the OS ITI. All groups are collapsed. Bars represent 95% CI for each session.

MSE = *3.3*, η_p^2 = 0.36.

Responding in the Blocking Test was measured as in Experiment 1. Responding to the six CS presentations during each of the two OS trials were averaged. Outliers were excluded from analysis as in Experiment 1 (2 from Group Block-Ext, and 3 from Group Blocking). A mixed ANOVA was performed with Trial (each of the two OS trials) as a within-subject factor and Group as a between-subject factor. This showed a non-significant Trial × Group interaction, $F(2, 28) = 1.67$, $p = .2$, *MSE* = *0.85*, $\eta_p^2 = 0.1$. The Group effect was significant, $F(2, 28) = 3.28$, $p = .046$, *MSE* = *5.3*, $\eta_p^2 = 0.2$, while the Trial effect was non-significant ($p > .15$). Planned comparisons showed that responding in groups Block-Ext and Blocking did not differ ($p > .62$), and that both of them responded less than the Control Group, $F(1, 28) = 6.7$, $p = .015$, *MSE* = *5.3*, $\eta_p^2 = 0.19$ (see left side of Fig. 4). Inclusion of outliers does not make this difference non-significant.

To evaluate RR, data of groups Blocking and Block-Ext were analyzed in a mixed ANOVA with Test (Blocking Test and RR Test) as a within-subjects factor, and Group as a between-subjects factor. The analysis showed no evidence of RR (see right side of Fig. 4, and compare to groups Blocking and Block-Ext on the left), as the Test × Group interaction was not significant, $F(1, 17) < .01$, $p = 0.94$, *MSE* = 1,67, $\eta_p^2 = 0.0003$. The RR test had more responding in general, $F(1, 17) = 4.81$, $p = 0.042$, *MSE* = 1.67, $\eta_p^2 = 0.22$, and the Group effect was non-significant, ($p = 0.61$). To evaluate whether extinguishing OS W alone deteriorate its modulatory properties, the data from Group Control was analyzed. Responding in both CS A trials during the OS

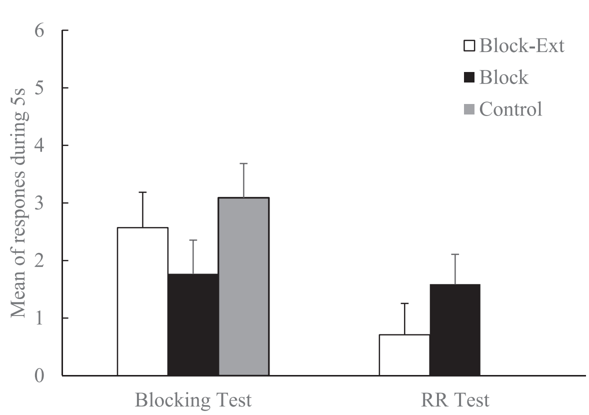

Fig. 4. Blocking Test and RR Test of Experiment 2.
Bars represent mean responses to the CS during the OS duration. Error bars represent 95% CI.

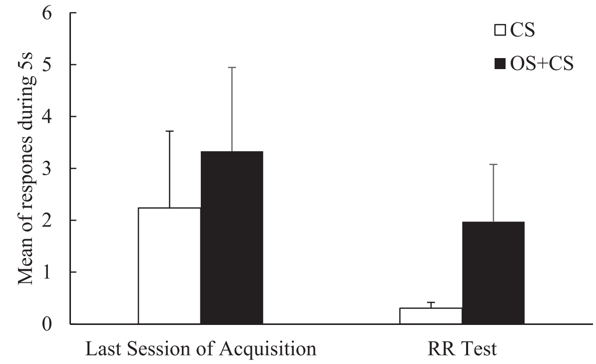

Fig. 5. Occasion setting assessment at the RR Test of Experiment 2.
OS + CS refers to mean responses to the CS during the OS duration. CS refers to mean responses to the CS during the OS ITI. Error bars represent 95% CI.

(OS + CS) were averaged, and during the OS ITI ("CS"). The data from this test were compared to the last session of the Training phase. These data were analyzed with a repeated measures ANOVA with Phase (Training and Test) and Measure (OS + CS and CS) as within-subject factors. This analysis revealed an effect of Measure, $F(1, 11) = 6.93$, $p = .02$, *MSE* = 3.3, $\eta_p^2 = 0.39$, indicating that responding to OS + CS was higher overall. The analysis also yielded an effect of Phase, $F(1, 11) = 19.19$, $p < .01$, *MSE* = 1.7, $\eta_p^2 = 0.63$, which indicates that subjects during Test had significantly lower responses. More importantly, there was no interaction, $F(1, 11) = 1.04$, $p = 0.33$, *MSE* = 0.93, $\eta_p^2 = 0.08$, indicating that a Pavlovian extinction of OS W does not reduce its modulatory potential, as the OS + CS measure remained higher than the CS. This result supports the view that the modulatory and Pavlovian properties of an OS are independent (see Fig. 5).

4. Experiment 3

We consistently observed blocking of occasion setting in Experiment 1 and Experiment 2. Experiment 3 continued with the aim to assess blocking of occasion setting. Specifically, we examined whether blocking of occasion setting can be observed during transference training with a compound OS. Transference refers to the ability of an OS to also modulate other CSs that were previously trained with a different OS (Holland, 1989). For this experiment, two groups were used (Groups Blocking and Control). During the first phase, all subjects were trained with a positive OS to CS A. During this phase Group Blocking received presentations of OS Y while Group Control received presentations of OS W, to control for blocking of occasion setting. In the next phase, blocking was trained by presenting OS Y in compound with OS X for both groups. Critically, for both groups this phase was carried using a different CS (B). Finally, OS X was tested with both CS A and CS B in two separate tests. Lower responses in the Blocking Group compared to the Control Group, in the OS + CS measure in each test, would be indicative of blocking of OS.

4.1. Subjects and apparatus

Subjects were 24 male Sprague Dawley descended young adult rats. Animals were single housed and treated as in Experiments 1 and 2. Animals were randomly assigned to one of two conditions (*ns* = 12). All apparatus and stimuli used were the same as in previous experiments, except the inclusion of CS B. CS B was either a 1000 Hz tone or a whitenoise and it was counterbalanced with CS A. Notice that CS A was counterbalanced among these two cues in all previous experiment (Table 3).

Table 3
Experiment 3 design.

Group	Training	Compound	Blocking Test	CR	Transference Test	CR
Blocking	Y → A+/A−	XY → B+ /B−	X → B−	cr	X → A−	cr
Control	W → A+/A−			CR		CR

Note. W, X and Y are light stimuli in different parts of the chamber, counterbalanced. A is a 1000 Hz tone or white-noise, of 8 dB over background noise, counterbalanced. + and − denote delivery or absence of the US, respectively. “cr”, “Cr” and “CR” indicate expected response levels for each group, from low to high, respectively.

4.2. Procedure

4.2.1. Acclimation and training

On Days 1–2, all animals received acclimation. On Days 3–9, subjects received one daily 45-min session of OS training. Training was conducted in a similar manner to the previous experiments.

4.2.2. Compound training

On Days 10 and 11, all animals received one daily 45-min session with the compound of two OS. In these sessions OSs Y and X were presented together, in a similar way to the previous experiments, with the only difference that CS B was presented instead of CS A.

4.2.3. Blocking test

On Day 12, all subjects received two presentations of X → B with no reinforcement in a 21-min session. Feature onset occurred at 3 and 12 min into session. CSs were programed to occur during the OS as described in Training 1.

4.2.4. Transference test

On Day 13, all subjects received two presentations of X → A with no reinforcement, with the same procedure described in the Blocking Test.

4.3. Results and discussion

This experiment trained an OS in two groups (Y for Group Blocking and W for Group Control). In a second phase, two OSs (XY) were trained in compound with a different CS (B). Both X and Y were new for the Control Group, but only X was new for the Blocking Group. When OS X was then tested with CS B, there was no difference between groups, showing no blocking of OS. Interestingly, when OS X was tested with CS A, used during the training of OS Y, blocking of occasion setting was observed, showing that blocking in this case only happened concerning the first trained CS A. The following analyses support these statements.

In the Training phase of Experiment 3, there were seven sessions, but due to equipment failure, only the last session data was logged. Responses were measures as in experiments 1 and 2. A mixed ANOVA was used to analyze the four Measures (Baseline, CS, OS, OS + CS) as a within-subjects factor and Group (Blocking and Control) as a between-subjects factor. The Measure × Group interaction was non-significant, $F(3, 66) = 0.27, p = .8, MSE = 2.59, \eta_p^2 = 0.011$. The Measure effect was significant, $F(3, 66) = 16.09, p < .01, MSE = 2.59, \eta_p^2 = 0.42$, while the Group effect was non-significant ($p = .87$). A planned comparison showed that the OS + CS measure was higher than either the OS or the CS measure $F(1, 22) = 18.4, p < .01, MSE = 2.47, \eta_p^2 = 0.45$, (see Fig. 6), indicative of occasion setting acquisition for CS A for both groups.

Responding in the Blocking Test was measured as in Experiment 1. We did not detect any outlier. A mixed ANOVA was performed with Trial (first and second OS trials of the Blocking Test) as a within-subjects factor, and Group (Blocking and Control) as a between-subjects factor. The results showed no Trial × Group interaction, $F(1, 20) = 0.16, p = .69, MSE = 2.03, \eta_p^2 = 0.008$. There was no Trial or Group main effects, (p = 0.35 and p = 0.63, respectively). A planned comparison showed that there was no blocking of the responses in the Blocking Group, $F(1, 20) = 0.22, p = .64, MSE = 10.48, \eta_p^2 = 0.01$ (see left side of Fig. 7).

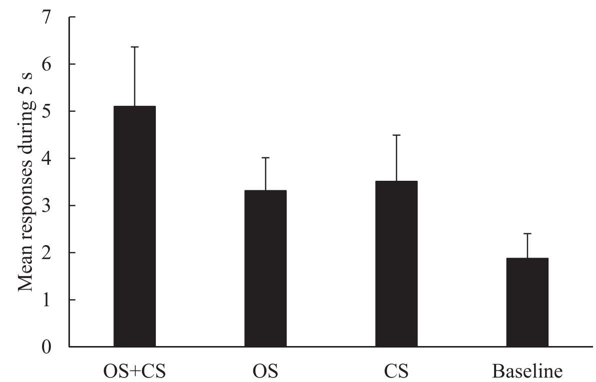

Fig. 6. Last session of Acquisition of Experiment 3.
Each bar represents a different measure. OS + CS is responding to the CS during the OS duration. CS is responding to the CS during the OS ITI. OS is responding during the 5 s prior to the CS onset during the OS duration. Baseline is responding to the 5 s prior to the CS onset during the OS ITI. All groups are collapsed. Error bars represent 95% CI for each measure.

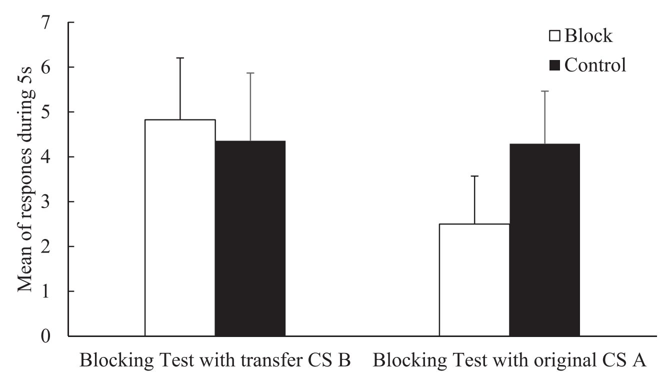

Fig. 7. Blocking tests of Experiment 3.
Bars represent mean responses to the CS during the OS duration. Error bars represent 95% CI.

Responding in the Transference Test was measured as in the Blocking Test. A mixed ANOVA was performed with Test (Blocking Test and Transference Test) and Trial (first and second OS trials of the Transference Test) as a within-subjects factors, and Group (Blocking and Control) as a between-subjects factor. There was no Test × Trial × Group interaction, $F(1, 20) = 0.45, p > .5, MSE = 1.8, \eta_p^2 = 0.022$. The Test × Group interaction was significant, $F(1, 20) = 27.85, p < .05, MSE = 5.8, \eta_p^2 = 0.19$. No other interaction was significant ($p > 0.17$). Of interest, a planned comparison showed lower responses on the Blocking Group (see right side of Fig. 7), $F(1, 20) = 5.54, p < .03, MSE = 6.3, \eta_p^2 = 0.22$. This result suggest that OS X was only blocked to CS A, the CS used in the Training phase. This result is particularly interesting as it shows a limit of the blocking of occasion setting.

5. General discussion

Three experiments aimed to assess whether occasion setting is susceptible of blocking in an analogy to the effect observed in Pavlovian conditioning. Moreover, the first two experiments had the additional objective of examining if extinguishing a blocking OS produced a retrospective revaluation of a blocked OS. The third experiment sought to examine the boundary conditions of blocking of occasion setting, to assess if the decrease in responding also happen if a new CS is prompted to be disambiguated in the compound phase or if it is necessary for occasion setting that the CS remains the same across phases.

Experiment 1 showed that establishing a positive OS (Y) of a CS (A) impairs responding to a new OS (X), when this new cue is trained in compound with the first one, i.e. blocking. However, presentations of OS Y with non-reinforced CS A (i.e., extinction) did not increase responding to CS A during OS X, as it was expected in a RR effect. The extinction procedure was modified in Experiment 2 by maintaining the number of USs and CSs delivered constant among groups but changing the contingency of the OS in relation to the CS in Group Block-Ext. Subjects showed a strong blocking of occasion setting, but the extinction procedure was again ineffective in increasing the responses to CS A during OS X. It is not clear what the analogous procedure would be for extinguish the OS. We tried the two most straightforward controls. Exposure to the context in Experiment 1 and partial reinforcement in Experiment 2. In these situations, we maintained the ambiguous relation between the CS and the US. Nevertheless, in Experiment 2 this also constitutes a retraining of A, given that there is no stimulus disambiguating it. Future experiments need to address this problem. One solution may use the training of two occasion setters (e.g., X and Y), each modulating its own CS at acquisition (e.g. A and B), and then at the compound training using only one of the CS (e.g., A). This leaves free CS B, which can be used to retrain the blocker OS at the Extinction phase without altering the experience to CS A.

Experiment 2 also tested whether behavioral control exerted by the OS was caused by the occasion setting properties or simple Pavlovian conditioning. If the target or the control OS were acting as Pavlovian stimuli, extinguishing the OS by itself should have decreased responding to the OS-CS compound to levels comparable to responding to the CS alone. The results showed, however, that responding to the OS and the CS together was overall higher than responding to the CS alone. This indicates that presenting the OS by itself does not impairs the ability of the OS to disambiguate the relationship between the CS and the US, which suggest that the procedure used in the three experiments is useful to produce occasion setting. It must be noted that under certain circumstances, two extinguished CSs can summate and produce CRs even if they, by themselves, no longer produce CR (Hendry, 1982). So, the result of the W → A− test may be explained by a summation of W with A, even if W was extinguished. This represents a limitation of the OS literature, as modulatory control after extinction of the CS has been typically used as evidence of an OS mechanism (e.g., Bouton and Swartzentruber, 1986; Holland, 1989). Parameters for the acquisition and measurement of occasion setting phenomena are still a concern in the literature (Delamater et al., 2017)

Taken together, these experiments showed that occasion setters are susceptible to blocking, in a similar manner to Pavlovian CSs. These results are consistent with those reported by Bonardi (1991), who showed blocking of occasion setting with a different control procedure than the present experiments, and Swartzentruber (1991), who showed other forms of blocking of occasion setting. However, the lack of evidence showing retrospective revaluation is inconsistent with a theoretical account of RR of a common underlying mechanism between occasion setting and simple Pavlovian conditioning. Retrospective revaluation has been found in blocking of Pavlovian conditioning in several reports (Aitken et al., 2001; Blaisdell et al., 1999; Dickinson and Burke, 1996), but consistent with our results, previous reports have also failed to find a RR effect of blocking (Dopson et al., 2009). It is worth noting that many of the experiments showing evidence of RR have used either a sensory preconditioning or a human causal judgment preparation, that is, stimuli without high biological relevance. The relationship between the OS and the CS has low biological relevance like the relationship between CSs in sensorial preconditioning, which may make the OS a good candidate for retrospective revaluation studies. However, occasion setting studies do have a US as part of the associative structure from the beginning, introducing biological relevance. Another important point is that the amount of extinction trials in the present experiment was moderate, compared to research in Pavlovian RR. Future Experiment should increase the number of Extinction trial parameter more in the line of other RR studies in Pavlovian learning. Considering this, the lack of RR in the present experiments should not be assumed as evidence against a similar underlying mechanism between Pavlovian conditioning and occasion setting, although it suggests, in line with the evidence, that RR of blocking might be dependent on specific parameters and thus a limited phenomenon in its scope.

Experiment 3 aimed to examine whether blocking of occasion setting also occurred during transfer of occasion setting. In this experiment, the compound phase was done with a different CS (B) to that used in training. Blocking was not observed when the target OS was tested with CS B, although there was blocking when subjects were tested with the OS and the original CS. This suggests that the blocking of OS may depend on the stimulus used in the compound training. The potential of an OS to disambiguate a CS was not affected when it was trained in compound with an OS that already disambiguated a different CS (i.e., Y → A). Nevertheless, is worth noting that when the OS was tested with the initial CS (i.e., a transference test), subjects in the Blocking Group showed fewer responses than the Control Group. This finding is counterintuitive because OS X was never trained with CS A.

The results of Experiment 3 can be understood analyzing the associations between OS and CS. First, the OS Y might have failed to transfer to the second CS during the compound training phase. Research has shown that occasion setters are specific to the CS that they are trained with and that they transfer their potential only under certain conditions (CS that have also been subjects of occasion setter, i.e., other ambiguous CSs; Bonardi et al., 2012) The CS used during the blocking phase was not an ambiguous CS at the start of this phase, and the potential of the OS Y may have not affected the training with the compound, that is, OS Y may have not worked as an OS at the start of the compound phase. The modulatory influence of an OS may be a necessary condition for blocking of OS to occur. As training progressed, the first OS (Y) may have been established as an OS with the new CS, but by that point the second OS (X) would already be a good enough OS. This is reflected in the Block Test, where both groups had similar responding. This explanation points to a potentially critical link in the OS mechanism between the OS and the CS with which it was trained (for a description of these potential links, see Holland, 1992). With the presentation of a new CS (B), this OS-CS ((Y-A)) link is no longer active, thus promoting the formation of a new association between the OS (Y) and the new CS (B), while a link between the new CS (B) and the second OS (X) is formed. This account is consistent with the results of the Transference Test. The link between the OS Y and the original CS A would be strong enough to block transference of the second OS X to CS A.

It is worth mentioning however, that the order of testing in Experiment 3 were not counterbalanced. All subjects passed to the Blocking Test in a session and the next day to the Transference Test. We do not have any theoretical reason to think that an order effect would yield difference in responding that look like blocking the transfer of X to A.

The results of Experiment 3 are also somewhat like studies in Pavlovian blocking in which a different US is used in the compound phase relative to the Training phase or some characteristics of the US is changed between phases (Mackintosh and Turner, 1971; Blaisdell et al., 1997). In those, changing either the intensity or physical properties of the US reduced or eliminated the amount of blocking. In a similar way, changing characteristics of the CS from Training to the Compound phase in Experiment 3, prevented any indication of blocking. This similarity adds to the list of analogies between occasion setting and standard Pavlovian conditioning preparations.

Nevertheless, this hypothesis suggests further research in a specific direction. It follows from the account described above that the blocking of transference should also work with a third ambiguous unrelated CS trained with the same US. In this case, the link between the OS and the CS should block the transference to this third CS. Such a test would give a more complete picture of the underlying mechanism of occasion setting. Secondly, it is possible that the second OS (X) did not lose all the transference potential but only specifically to the first CS due to its presentations during the compound phase. In other words, blocking of the second OS could be specific to the first CS, and this might be modulated through a within-compound association between both OSs. Whether there is such an association and its nature should be the focus of future research.

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References

Aitken, M.R.F., Larkin, M.J.W., Dickinson, A., 2001. Re-examination of the role of within-compound associations in the retrospective revaluation of causal judgements. Q. J. Exp. Psychol. B: Comp. Physiol. Psychol. 54 (1), 27–51. http://dx.doi.org/10.1080/02724990042000029.

Baker, A.G., Murphy, R.A., Mehta, R., 2003. Learned irrelevance and retrospective correlation learning. Q. J. Exp. Psychol.: Sect. B 56 (1), 90–101. http://dx.doi.org/10.1080/02724990244000197.

Blaisdell, A.P., Denniston, J.C., Miller, R.R., 1997. Unblocking with qualitative change of unconditioned stimulus. Learn. Motiv. 28 (2), 268–279. http://dx.doi.org/10.1006/lmot.1996.0961.

Blaisdell, A.P., Gunther, L.M., Miller, R.R., 1999. Recovery from blocking achieved by extinguishing the blocking CS. Anim. Learn. Behav. 27 (1), 63–76. http://dx.doi.org/10.3758/BF03199432.

Bonardi, C., Bartle, C., Jennings, D., 2012. US specificity of occasion setting: hierarchical or configural learning? Behav. Process 90 (3), 311–322. http://dx.doi.org/10.1016/j.beproc.2012.03.005.

Bonardi, C., 1991. Blocking of occasion setting in feature-positive discriminations. Q. J. Exp. Psychol. B: Comp. Physiol. Psychol. 43 (4), 431–448. http://dx.doi.org/10.1080/14640749108401278.

Bouton, M.E., Swartzentruber, D., 1986. Analysis of the associative and occasion-setting properties of contexts participating in a Pavlovian discrimination. J. Exp. Psychol. Anim. Behav. Process. 12 (4), 333. http://dx.doi.org/10.1037/0097-7403.12.4.333.

Cole, R.P., Gunther, L.M., Miller, R.R., 1997. Spontaneous recovery from the effect of relative stimulus validity. Learn. Motiv. 28 (1), 1–19. http://dx.doi.org/10.1006/lmot.1997.0949.

Delamater, A.R., Derman, R.C., Harris, J.A., 2017. Superior ambiguous occasion setting with visual than temporal feature stimuli. J. Exp. Psychol.: Anim. Learn. Cognit. 43 (1), 72–87. http://dx.doi.org/10.1037/xan0000122.

Delamater, A.R., Kranjec, A., Fein, M.I., 2010. Differential outcome effects in Pavlovian biconditional and ambiguous occasion setting tasks. J. Exp. Psychol. Anim. Behav. Process. 36 (4), 471–481. http://dx.doi.org/10.1037/a0019136.

Dickinson, A., Burke, J., 1996. Within-compound associations mediate the retrospective revaluation of causality judgments. Q. J. Exp. Psychol. B: Comp. Physiol. Psychol. B 49 (1), 60–80. http://dx.doi.org/10.1080/713932614.

Dickinson, A., Shanks, D., Evenden, J., 1984. Judgment of act-outcome contingency: the role of selective attribution. Q. J. Exp. Psychol. A: Hum. Exp. Psychol. 36 (1), 29–50. http://dx.doi.org/10.1080/14640748408401502.

Dopson, J.C., Pearce, J.M., Haselgrove, M., 2009. Failure of retrospective revaluation to influence blocking. J. Exp. Psychol. Anim. Behav. Process. 35 (4), 473–484. http://dx.doi.org/10.1037/a0014907.

Franssen, M., Claes, N., Vervliet, B., Beckers, T., Hermans, D., Baeyens, F., 2017. Reinstatement after human feature-positive discrimination learning. Behav. Process 137, 73. http://dx.doi.org/10.1016/j.beproc.2017.01.007.

Hendry, J.S., 1982. Summation of undetected excitation following extinction of the CER. Anim. Learn. Behav. 10 (4), 476–482. http://dx.doi.org/10.3758/BF03212287.

Holland, P.C., 1983. Occasion setting in Pavlovian feature positive discriminations. In: Commons, M.L., Herrnstein, R.J., Wagner, A.R. (Eds.), Quantitative Analyses of Behavior: Discrimination Processes. Ballinger, New York, NY, pp. 183–206.

Holland, P.C., 1985. The nature of conditioned inhibition in serial and simultaneous feature negative discriminations. In: Miller, R.R., Spear, N.E. (Eds.), Information Processing in Animals: Conditioned Inhibition. Erlbaum, Hillsdale, NJ, pp. 267–297.

Holland, P.C., 1989. Feature extinction enhances transfer of occasion setting. Anim. Learn. Behav. 17 (3), 269–279. http://dx.doi.org/10.3758/BF03209799.

Holland, P.C., 1992. Occasion setting in Pavlovian conditioning. In: Medin, D.L. (Ed.), The Psychology of Learning and Motivation. Academic Press, San Diego, CA, pp. 69–125.

Kamin, L.J., 1969. Predictability, surprise, attention, and conditioning. In: Campbell, B.A., Church, R.B. (Eds.), Punishment and Aversive Behavior. Appleton Century-Crofts, New York, NY, pp. 279–296.

Kaufman, A., Bolles, R.C., 1981. A nonassociative aspect of overshadowing. Bull. Psychon. Soc. 18 (6), 318–320.

Leising, K.J., Bonardi, C., 2017. Occasion setting. Behav. Process 137, 1–4. http://dx.doi.org/10.1016/j.beproc.2017.02.009.

Lubow, R.E., Moore, A.U., 1959. Latent inhibition: the effect of nonreinforced pre-exposure to the conditional stimulus. J. Comp. Physiol. Psychol. 52 (4), 415. http://dx.doi.org/10.1037/h0046700.

Mackintosh, N.J., Turner, C., 1971. Blocking as a function of novelty of CS and predictability of UCS. Q. J. Exp. Psychol. 23 (4), 359–366. http://dx.doi.org/10.1080/14640747108400245.

Matzel, L.D., Schachtman, T.R., Miller, R.R., 1985. Recovery of an overshadowed association achieved by extinction of the overshadowing stimulus. Learn. Motiv. 16 (4), 398–412. http://dx.doi.org/10.1016/0023-9690(85)90023-2.

Miller, R.R., Oberling, P., 1998. Analogies between occasion setting and Pavlovian conditioning. In: Schmajuk, N.A., Holland, P.C. (Eds.), Occasion Setting: Associative Learning and Cognition in Animals. American Psychological Association, Washington, DC, pp. 3–35.

Moore, J.W., Choi, J.S., 1998. Conditioned stimuli are occasion setters. In: Schmajuk, N.A., Holland, P.C. (Eds.), Occasion Setting: Associative Learning and Cognition in Animals, pp. 279–318. http://dx.doi.org/10.1037/10298-010.

Oberling, P., Gunther, L.M., Miller, R.R., 1999. Latent inhibition and learned irrelevance of occasion setting. Learn. Motiv. 30 (2), 157–182. http://dx.doi.org/10.1006/lmot.1999.1029.

Pavlov, I.P., 1927. Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral cortex. Oxford University Press, London.

Rescorla, R.A., 1985. Conditioned inhibition and facilitation. In: Miller, R.R., Spear, N.E. (Eds.), Information Processing in Animals: Conditioned Inhibition. Erlbaum, Hillsdale, NJ, pp. 299–326.

Rescorla, R.A., 1986a. Extinction of facilitation. J. Exp. Psychol. Anim. Behav. Process. 12 (1), 16–24. http://dx.doi.org/10.1037/0097-7403.12.1.16.

Rescorla, R.A., 1986b. Facilitation and excitation. J. Exp. Psychol. Anim. Behav. Process. 12 (4), 325–332. http://dx.doi.org/10.1037/00977403.12.4.325.

Rescorla, R.A., 1987. Facilitation and inhibition. J. Exp. Psychol. Anim. Behav. Process. 13 (3), 250–259. http://dx.doi.org/10.1037/0097-7403.13.3.250.

Ross, R.T., 1983. Relationships between the determinants of performance in serial feature-positive discriminations. J. Exp. Psychol. Anim. Behav. Process. 9 (4), 349–373. http://dx.doi.org/10.1037/0097-7403.9.4.349.

Shanks, D.R., 1985. Forward and backward blocking in human contingency judgement. Q. J. Exp. Psychol. B: Comp. Physiol. Psychol. 37 (1), 1–21. http://dx.doi.org/10.1080/14640748508402082.

Swartzentruber, D., 1991. Blocking between occasion setters and contextual stimuli. J. Exp. Psychol. Anim. Behav. Process. 17 (2), 163–173. http://dx.doi.org/10.1037/0097.

Trask, S., Thrailkill, E.A., Bouton, M.E., 2017. Occasion setting, inhibition, and the contextual control of extinction in Pavlovian and instrumental (operant) learning. Behav. Process 137, 64–72. http://dx.doi.org/10.1016/j.beproc.2016.10.003.

Vogel, E.H., Ponce, F.P., Wagner, A.R., 2017. A theoretical analysis of transfer of occasion setting: SOP with replaced elements. Behav. Process 137, 19–32. http://dx.doi.org/10.1016/j.beproc.2016.06.013.