

# Narrowing down the conditions for extinction of Pavlovian feature-positive discriminations in humans

Priya R. van Vooren · Mathijs Franssen · Tom Beckers · Dirk Hermans · Frank Baeyens

Published online: 11 January 2012  
© Psychonomic Society, Inc. 2012

**Abstract** The aim of this study was to delineate the minimal conditions for extinction of Pavlovian modulation in humans. Previous experiments at our lab showed that, after  $X \rightarrow A+/A-$  acquisition training,  $X-$  trials did not extinguish differential  $X \rightarrow A+/A-$  responding, while  $X \rightarrow A-$  trials did. Additionally,  $X \rightarrow A-$  extinction training seemed only to extinguish differential  $X \rightarrow A+/A-$  responding, while leaving differential responding on a concurrently trained  $Y \rightarrow B+/B-$  discrimination intact. It thus seemed that the  $X \rightarrow A+/A-$  discrimination can only be extinguished by  $X \rightarrow A-$  extinction trials. (Rescorla, *Journal of Experimental Psychology: Animal Behavior Processes* 12, 16–24, 1986), on the other hand, found that the minimal conditions for extinction were broader in pigeons: Namely, he found that an acquired  $X \rightarrow A+/A-$  discrimination could be extinguished by presenting the original feature X in combination with a different target (B) that was minimally trained as an exciter. We thus wanted to examine whether this was also the case in humans. We found that nonreinforced  $X \rightarrow B-$  presentations did not abolish discriminative  $X \rightarrow A/A$  responding when target B was a nonreinforced stimulus. Nonreinforced  $X \rightarrow B-$  trials did extinguish the  $X \rightarrow A+/A-$  discrimination when target B had previously been trained as a target for modulation ( $X \rightarrow B+/B-$  or  $Y \rightarrow B+/B-$  training) or as a reinforced exciter (B+). Our results thus parallel and extend those in nonhuman animals (Rescorla, *Journal*

*of Experimental Psychology: Animal Behavior Processes* 12, 16–24, 1986).

**Keywords** Occasion setting · Feature-positive modulation · Transfer · Extinction · Humans

In a classical conditioning procedure, the contingent pairing of a conditioned stimulus (CS) with a (biologically significant) unconditioned stimulus (US) results in the formation of an association between the representations of these two events. That is, a simple CS comes to elicit conditioned responding (CR) because it signals the occurrence of a US. More complex situations also exist, however. In a sequential feature-positive Pavlovian discrimination task, the CS predicts the US in some instances, whereas it does not do so in other instances. For example, a target A (the CS) may be followed by a US if that target is preceded by a feature X. However, target A will not be reinforced when it is presented on its own. This relationship can be depicted as follows:  $X \rightarrow A+/A-$ . Here, feature X, also called a *positive occasion setter*, actually signals that target A will be followed by a reinforcer (Schmajuk, Lamoureux, & Holland, 1998). Several studies support the differentiation between simple Pavlovian CSs and occasion setters at a functional level (Holland, 1992). At least two characteristics justify the distinction.

A first characteristic entails the orthogonality relation between the excitatory and modulatory powers of a cue. In a feature-positive discrimination, an occasion setter X can have modulatory powers that cannot be reduced to, and are even independent of, X's own direct excitatory associations with the US (Holland, 1983; see R. R. Miller & Oberling, 1998; Ross, 1983; Ross & LoLordo, 1986). This orthogonality relation becomes apparent after feature extinction. Nonreinforced  $X-$  presentations readily attenuate the direct

P. R. van Vooren · M. Franssen · T. Beckers · D. Hermans · F. Baeyens (✉)  
Department of Psychology, University of Leuven,  
Tiensestraat 102,  
B-3000 Leuven, Belgium  
e-mail: frank.baeyens@ppw.kuleuven.be

T. Beckers  
Department of Clinical Psychology, University of Amsterdam,  
Amsterdam, The Netherlands

excitatory X–US association, but leave X’s modulatory powers resulting from (sequential) feature-positive discrimination training largely intact (e.g., Skinner, Martin, Pridgar & Van der Kooy, 1994, Exp. 3). Extinction of modulation can instead be obtained by presenting a replication of the training trials, but reversing the reinforcement contingencies—that is,  $X \rightarrow A-/A+$  after original  $X \rightarrow A+/A-$  training (Rescorla, 1986). In fact, even without the addition of  $A+$  trials,  $X \rightarrow A-$  trials appear sufficient to abolish differential responding (R. R. Miller & Oberling, 1998). As such, the extinction of occasion setting is actually analogous to the extinction of Pavlovian conditioning. That is, in both cases, extinction treatment only appears to be effective when it contains information that contradicts what has previously been learned (Baeyens et al., 2005).

A second characteristic that justifies the distinction concerns the transfer potential of a feature X to a new target B—that is, a target that differs from the one that was involved in the original training (A). Simple Pavlovian exciters combine their influence with the excitatory or inhibitory value of new targets linearly and additively, irrespective of the acquisition history of that new target (Holland, 1992). The transfer potential of occasion setters, on the other hand, is much more selective and limited than that of simple Pavlovian CSs. That is, the original feature X will transfer its modulatory powers to a new target B if that B was previously part of an occasion-setting relationship or had become ambiguous during prior training.

Rescorla (1986) conducted a profound and systematic analysis of the processes involved and the specific conditions of the extinction of feature-positive modulation. He used an autoshaping procedure with pigeons and demonstrated that nonreinforced presentations of the feature in compound with the original target ( $X \rightarrow A-$ ) attenuated differential responding, whereas nonreinforced presentations of the feature alone ( $X-$ ) did not. Subsequently, he investigated whether differential responding might disappear after nonreinforced presentations of a feature in conjunction with a target that differed from the one used in the original discrimination training ( $X \rightarrow B$ ) and explored what the minimal requirements were for a target B to produce this result. He found that a loss of modulation of the original discrimination was dependent on the excitatory state of the new target with which the feature was nonreinforced. That is,  $X \rightarrow B-$  presentations led to an attenuation of the original  $X \rightarrow A+/A-$  discrimination if B was an exciter, but not if B had previously been nonreinforced.

Rescorla’s (1986) results are important because they enlarge our understanding of the conditions of the extinction of modulation. However, these experiments were conducted in nonhuman animals; evidence suggests that findings on occasion setting in nonhuman animals cannot always be transferred directly to occasion setting in humans (see Baeyens, Vansteenwegen, Hermans, Vervliet, & Eelen, 2001). For example, while animals commonly approach simultaneous

feature-positive discriminations in an elemental way, humans more often use a configural learning strategy in these instances (Baeyens et al., 2001). Thus, the principles that govern occasion setting in humans seem to some extent different from those that govern occasion setting in other animals; the same may well be true for the principles that govern the extinction of modulation. Getting a clear picture of the conditions for the extinction of occasion setting in humans may help elucidate the conditions for successful exposure treatments. Clinical exposure is widely regarded to reflect associative extinction (Hermans, Craske, Mineka, & Lovibond, 2006). Understanding the conditions of extinction of more complex forms of acquisition—such as are studied in feature-positive discrimination learning—may improve exposure treatments and enhance their outcomes. Suppose that in a situation in which one is confronted with a fearsome stimulus (i.e., an aversive US), several discrete cues (i.e., CSs) are present. For instance, when shopping in the mall (context), at a certain moment while surrounded by a crowd (CS X) and experiencing minor palpitations (CS A), one is suddenly struck by a hyperventilation-induced panic attack (US). When running in a quiet forest and experiencing palpitations, on the other hand, no fear is elicited. The person might attribute the palpitations to his/her physical activity. So, crowd  $\rightarrow$  palpitation<sup>+</sup> (panic attack)/physical exercise  $\rightarrow$  palpitation<sup>−</sup> (no panic attack). Thus, palpitation has actually become an ambiguous stimulus. Namely, although the palpitation experience may be perceptually identical in both situations, the elicitation of a panic attack is conditional on the presence of other stimuli. Crucially, these other stimuli do not acquire behavioral control themselves: Being in a crowd does not produce a panic attack directly. In this example, “being in a crowd” can be said to modulate the anxiety induced by palpitations (leading to panic attack).

Basic findings on the extinction of occasion setting show that nonreinforced feature presentations do not extinguish the feature-positive discrimination (Baeyens et al., 2001; Rescorla, 1986). Nonreinforced feature  $\rightarrow$  target<sup>−</sup> presentations, on the other hand, do seem sufficient to extinguish differential responding (R. R. Miller & Oberling, 1998). Thus, exposing a person to the crowd (or palpitations) alone will not help extinguish the fear one has of a crowd in combination with palpitations. Conversely, exposing a person to a crowd in combination with palpitations should readily extinguish the fear of it.

Rescorla (1986) found that the minimal conditions for extinction were broader in pigeons. Namely, he found that an acquired  $X \rightarrow A+/A-$  discrimination could be extinguished by presenting the original feature X in combination with a different target (B) that was minimally trained as an exciter. This would imply that exposing the fearful person to a crowd in combination with another stimulus that minimally evokes fear (of the US) would also extinguish the crowd  $\rightarrow$  palpitations<sup>+</sup>/physical activity  $\rightarrow$  palpitations<sup>−</sup> discrimination.

We have to keep in mind though, that Rescorla (1986) found this effect in pigeons. For these reasons, the results need replication in a human Pavlovian conditioning preparation.

We investigated the effect of  $X \rightarrow B-$  presentations on an acquired  $X \rightarrow A+/A-$  discrimination in humans and attempted to gain insight into the properties that target B must have in order to result in the extinction of modulation. Thus, after  $X \rightarrow A+/A-$  training, we studied the effect of nonreinforced presentations of feature X in conjunction with a neutral stimulus ( $B-$ ), an exciter ( $B+$ ), or a target stimulus that had been subject to modulation by another feature ( $Y \rightarrow B+/B-$ ) or by the same feature ( $X \rightarrow B+/B-$ ). Rescorla looked at the effect of  $X \rightarrow B-$  presentations on an  $X \rightarrow A+/A-$  discrimination. In his experiment, target B was held neutral in one group but was presented reinforced in the other group. By adding two more groups, we created a design with a hierarchical structure going from general (neutral or nonreinforced target training) to specific (target that had been modulated by the feature used in the initial discrimination training). That is, at the most general level, we wanted to explore whether nonreinforced presentations of the original feature (X) in conjunction with just any target (e.g., target B) would lead to extinction of the  $X \rightarrow A+/A-$  discrimination. Alternatively, a novel target B might need to have a history of reinforcement to lead to such a result. If so, our results would coincide with Rescorla's (1986) findings in pigeons. Yet another possibility is that target B would need to have a history of modulation with any feature (e.g.,  $Y \rightarrow B+/B-$  training) or, at the most specific level, with the feature used in the original  $X \rightarrow A+/A-$  discrimination training ( $X \rightarrow B+/B-$  training) in order for  $X \rightarrow B-$  training to lead to the extinction of differential  $X \rightarrow A/A$  responding.

We made use of the Martians computer preparation (developed by Arcediano, Ortega, & Matute, 1996). This is an online conditioned suppression task that has been repeatedly used to study occasion setting in humans (Baeyens et al., 2001). Analogous to a conditioned suppression preparation in animals, participants first learn to emit a regular pattern of operant responding (i.e., bar pressing). Subsequently, several stimuli are introduced. At first, these stimuli will not affect the stable pattern of operant responding. Then some will be presented contingent with (and thus predictive of) a US, which will result in suppressed responding. In the Martians preparation, an instructional US is used, in contrast to the biologically significant US (e.g., shock) generally used in animals.

## Method

Table 1 summarizes the design of the experiment. The main goal was to find out whether the involvement of target A is essential in extinguishing an  $X \rightarrow A+/A-$

discrimination, or whether the disappearance of differential  $X \rightarrow A+/A-$  responding can also be achieved by non-reinforced presentations of the original feature in conjunction with a target that differs from the one used in the original discrimination training ( $X \rightarrow B$ ).

Participants were randomly assigned to one of four groups ( $n=10$  for each group), differing with respect to the nature of the target B training that they were exposed to. Training only varied across groups during the Acquisition 2 and acquisition reminder phases. At all other moments, participants received the same treatments. First, all participants received sequential  $X \rightarrow A+/A-$  discrimination training, followed by a test. Subsequently, the Acquisition 2 phase was introduced, which involved training with a non-reinforced target ( $B-$ ), an excitatory target ( $B+$ ) that was reinforced 80% of the time, or a target stimulus that had been subject to modulation by another feature ( $Y \rightarrow B+/B-$ ) or by the same feature ( $X \rightarrow B+/B-$ ), for groups [ $B-$ ], [ $B+$ ], [ $Y \rightarrow B+/B-$ ], and [ $X \rightarrow B+/B-$ ], respectively. This stage was also followed by a test. Then the acquisition reminder stage was inserted. Here, the acquisition trials of the previous two phases were intermixed, with a test given at the end. During the Acquisition 1, Acquisition 2, and acquisition reminder stages, every sequential feature  $\rightarrow$  target compound was reinforced 80% of the time. In group [ $B+$ ], target B was also reinforced on 80% of the Acquisition 2 and acquisition reminder trials. This partial reinforcement was used to attenuate the contrast between the reinforced acquisition trials and the nonreinforced test trials, so that participants would not perceive the test trials as a change in the experimental contingencies (Baeyens et al., 2001). The partial reinforcement schedule also served to keep the task challenging enough to hold students' attention throughout the experiment. Features X and Y and targets A and B were neutral stimuli of different sensory modalities (visual features were combined with auditory targets, or vice versa), counterbalanced within each group.

## Participants

Our aim was to include 40 participants (10 per subgroup). Students were excluded from the data analyses if they had not acquired differential  $X \rightarrow A/A$  responding at the acquisition reminder stage. Seven of the students were replaced because they did not meet this inclusion criterion. A total of 47 undergraduate students thus participated in the experiment as partial fulfillment of their course requirements. The statistical analyses were based on the data of the 40 participants (33 females, 7 males; ages 18–25 years) who mastered the  $X \rightarrow A+/A-$  discrimination. None of them had prior experience with the Martians task, and they were all uninformed about the goal of the experiment. Participants were randomly assigned to one of the four experimental

**Table 1** Design of the experiment

Group (N=40)	Phase 1						Transfer Test	Phase 2	
	Acquisition 1	Acquisition Test 1	Acquisition 2	Acquisition Test 2	Acquisition Reminder	Acquisition Reminder Test		Extinction	Final Test
B-			15 B-	B-	4 X→A+, 5 A-, 1 X→A- 5 B-	X→A-, A-, X- B-			
B+			12 B+ 3 B-	B-	4 X→A+, 5 A-, 1X→A- 4 B+, 1 B-	X→A-, A-, X- B-			
Y→B+/B-	12 X→A+ 15 A- 3 X→A-	X→A- A- X-	12 Y→B+ 15 B- 3 Y→B-	Y→B- B- Y-	4 X→A+, 5 A-, 1X→A- 4 Y→B+, 5 B-, 1Y→B-	X→A-, A-, X- Y→B-, B-, Y-	X→B- B-	20 X→B-	X→A- X→B- A- B- X- Y→B- Y-
X→B+/B-			12 X→B+ 15 B- 3 X→B-	X→B- B- X-	4 X→A+, 5 A-, 1X→A- 4 X→B+, 5 B-, 1X→B-	X→A-, A-, X- X→B-, B-, X-			

X and A are the 1.5-s presentation of a complex sound pattern and the 1.5-s full-screen presentation of a golden-brown background pattern, counterbalanced over participants. Y and B are the 1.5-s presentation of another complex sound pattern and the 1.5-s full-screen presentation of a marble-green background pattern, also counterbalanced. Whenever applicable, X and Y or A and B were stimuli from the same sensory modality for each participant. X→A (or Y→B, X→B) denotes serial presentation of the feature and target stimuli. A “→” sign represents a 1.5-s interstimulus interval. A “+” sign signifies a reinforced trial (0.5-s white flashing screen plus another complex sound pattern), and a “-” sign refers to a nonreinforced trial. The critical stimuli were presented for 3 s instead of for 1.5 s on test trials.

groups. Feature X was a visual stimulus and target A an auditory stimulus for half of the participants within each group, and these conditions were reversed for the other half of the participants within each group. All participants were tested individually. The length of the experiment was about 40 min.

**Apparatus and stimuli**

The experiment was run on a Pentium III 730-MHz, 128-MB RAM PC (Dell Optiplex GX110), and responding involved pressing the space bar on the computer keyboard. We used the Martians for Windows 95 software to program our experiment (Baeyens & Clarysse, 1998). The critical stimuli were features X and Y, targets A and B, and the US. Feature X and target A were the 1.5-s presentation of a complex sound pattern (Windows 95 “Sixties menu command.wav,” played in continuous loops through Altec Lansing Multimedia ACS90 computer speakers), and the 1.5-s full-screen presentation of a golden-brown background pattern (Windows 95 “gold.bmp,” tiled presentation), counterbalanced. Feature Y and target B were the 1.5-s presentation of another

complex sound pattern (Windows 95 “Windows 95 maximize.wav,” played back in continuous loops) and the 1.5-s full-screen presentation of a marble-green background pattern (Windows 95 “marble.bmp,” tiled presentation), also counterbalanced. Thus, all of the stimulus presentations during the training trials lasted 1.5 s; the feature and target presentations on X → A, X → B, and Y → B trials were separated by a 1.5-s empty time interval. On test trials, stimuli X, Y, A, and B (when presented alone) appeared for 3 s instead of 1.5 s. When a feature → target compound was presented during test trials, the feature and the empty time interval ( → ) lasted for 1.5 s, whereas the duration of the target was prolonged to 3 s. This lengthening from 1.5 to 3 s was done to enhance the sensitivity of the suppression measure. In the course of acquisition training, participants could experience that key pressing was safe during early target A presentation, and that refraining from bar pressing was thus only necessary toward the end of the 1.5-s target presentation. Hence, lengthening the test trial to 3 s made it possible to capture the stronger suppression of bar pressing after approximately 1.5 s. All of the assessment trials during the major tests (Acquisition Test 1, Acquisition Test 2, acquisition

reminder test, transfer test, and final test) were nonreinforced. Response data were collected from these major test trials.

The US consisted of a 0.5-s white, flashing screen (5 flashes at a rate of 10 flashes/s) and a 0.5-s complex sound pattern (Windows 95 “In the computer program error.wav,” played in continuous loops). The intertrial interval (ITI) was variable, with a range between 7.5 and 12.5 s (mean 10 s). Martians (green head and red eyes, mouth and antennae displayed against a yellow background) and explosions (red star on a gray background) were  $1.76 \times 1.76$  cm and appeared at intervals of 0.25 s on a black background. The distance between every Martian and/or explosion was 0.5 cm. Martians appeared one by one in rows on the screen from left to right and from top to bottom. When the screen was filled (7 rows of 10 Martians), the stimuli shifted up one row at a time to ensure a continuous progression between screens.

### Procedure

The procedure was modeled after the one used by Baeyens et al. (2001).

*Pretraining* The pretraining phase was introduced in order to teach participants to emit a steady pattern of operant responding. Participants were told to prevent Martians from landing on Earth by destroying them with their laser gun (= spacebar of the computer keyboard). Since a new Martian became visible every quarter of a second, regular bar pressing was necessary in order to destroy every single one. If a participant pressed the spacebar just before the Martian came into view, a depiction of an explosion appeared instead of a Martian. Only one bar press was allowed per Martian. If the spacebar was held down, a Martian rather than an explosion would appear. Participants were encouraged to destroy as many Martians as possible. No features (X, Y) or targets (A, B), nor the US, were presented during this stage. The pretraining phase ended when 100 Martians had landed. At that time, the screen was cleared and a box that contained information about the numbers of hits and misses and the percentage of Martians killed during this phase appeared on the screen.

*US-only phase* In this phase, an instructional US was introduced. Participants were told that the Martians had developed a powerful antilaser shield and that they were advised to refrain from bar pressing just before the antilaser shield was switched on, since this would trigger an invasion (= landing of many Martians) that could not be stopped. Aside from the verbal instructions, participants were shown what the US consisted of (see the Apparatus and Stimuli section above) and received a demonstration (by the experimenter) of what would happen if they stopped or, conversely, continued shooting (bar pressing) throughout the US. In total,

four USs were presented with an average ITI of 7.5 s (minimum 5 s, maximum 10 s). During the US, Martians appeared on the screen at the same pace as during the ITIs. If no response was registered in this period, nothing else happened. However, if a bar press was emitted, an invasion was triggered. This invasion lasted for 5 s, resulted in a new Martian appearing on the screen every 0.1 s while a white flashing screen (10 flashes/s) was presented that coincided with another complex sound pattern (Windows 95 “Robotz ~2.wav,” played in continuous loops). At the end of this phase, feedback was given about the numbers of hits and misses and the percentage of Martians killed. Participants were made aware of the drop in the percentage of Martians killed caused by the safe landing of many Martians during an invasion, and they were encouraged to destroy as many Martians and avoid as many invasions as possible.

*Acquisition 1 and 2 and acquisition reminder + tests* At this point, stimuli X, Y, A, and B were introduced. The instrumental baseline task continued unaltered (= one Martian appearing every quarter of a second) during these stimulus presentations. During the Acquisition 1 phase, participants received sequential  $X \rightarrow A+/A-$  discrimination training. They were told that certain indicators would help them predict when the Martians were about to switch on their antilaser shield ( $X \rightarrow A+$ ) or were not ( $A-$ ). It was therefore essential to learn to distinguish between these indicators, since these would always enable participants to avoid shooting while the antilaser shield was in operation.  $X \rightarrow A$  signaled that the antilaser shield would come into operation and made nonresponding during this period the best option. Trials on which target A was presented alone, conversely, indicated that the US would not be delivered, making continuous bar pressing preferable. Participants were not informed about the nature of the aforementioned contingencies but were expected to learn them while playing the game.

In total, 12  $X \rightarrow A+$ , 3  $X \rightarrow A-$ , and 15  $A-$  trials were presented. They were subdivided into three equivalent sequential blocks. The trial sequence was semirandom (i.e., no more than two identical consecutive trials were allowed within each block). Furthermore, the order of trial presentation was different for every participant. The  $X \rightarrow A$  compound was only reinforced on 80% of the trials (see above). An Acquisition Test 1 followed Acquisition 1. In this  $X \rightarrow A$  test, A and X were each presented once, nonreinforced, to evaluate the acquisition of differential  $X \rightarrow A/A$  responding.

The Acquisition 2 phase followed Acquisition Test 1 without interruption and consisted of a treatment that varied among the four groups. In group [B-], acquisition training consisted of 15 nonreinforced target B- presentations. Participants in group [B+] received excitatory training in which 12 reinforced B+ and 3 nonreinforced B- trials were given. Training in groups [Y  $\rightarrow$  B+/B-] and [X  $\rightarrow$  B+/B-] did not

differ from the initial  $X \rightarrow A+/A-$  training, except for the identity of the (feature and) target. Acquisition Test 2 immediately followed Acquisition 2. Participants in groups [B−] and [B+] received one nonreinforced target B presentation. Participants in group  $[Y \rightarrow B+/B-]$  received one nonreinforced presentation each of  $Y \rightarrow B$ , B, and Y. Group  $[X \rightarrow B+/B-]$  received the same presentations as group  $[Y \rightarrow B+/B-]$ , but feature Y was replaced by feature X in this group. Subsequently, an acquisition reminder stage was presented in which the prior Acquisition 1 and 2 training trials were presented intermixed, to refresh the previously learned contingencies. Four  $X \rightarrow A+$ , 5  $A-$ , and 1  $X \rightarrow A-$  trials were presented in all groups. In group [B−], these  $X \rightarrow A+/A-$  acquisition trials were accompanied by 5 B− trials. In group [B+], they were intermixed with 4 B+ and 1 B− trials. The acquisition reminder trials of group  $[Y \rightarrow B+/B-]$  were identical to the  $X \rightarrow A+/A-$  acquisition reminder trials, except for the identities of the feature and target. The acquisition reminder trials of group  $[X \rightarrow B+/B-]$  were also identical to the  $X \rightarrow A+/A-$  acquisition reminder trials, but this time the only difference was the identity of the target of the second discrimination (B instead of A). Participants who did not exhibit more suppression to  $X \rightarrow A$  than to A at this point were excluded from the analysis (see the Participants section). The subsequent acquisition reminder test phase measured the acquisition of differential  $X \rightarrow A/A$  training, in addition to acquisition of B− training in group [B−], B+ training in group [B+],  $Y \rightarrow B+/B-$  training in group  $[Y \rightarrow B+/B-]$ , and  $X \rightarrow B+/B-$  training in group  $[X \rightarrow B+/B-]$ .

*Transfer test, extinction, and final test* The transfer test immediately followed the previous stage and contained 1  $X \rightarrow B-$  and 1 B− trial. Subsequently, an extinction phase was introduced that consisted of 20  $X \rightarrow B-$  presentations

Ultimately, participants received a final test. For groups [B−], [B+], and  $[X \rightarrow B+/B-]$ , this phase consisted of one nonreinforced presentation apiece of an  $X \rightarrow A$ ,  $X \rightarrow B$ , A, B, and X trial. In group  $[Y \rightarrow B+/B-]$ , the assessment consisted of one nonreinforced  $X \rightarrow A$ ,  $X \rightarrow B$ ,  $Y \rightarrow B$ , A, B, X, and Y trial. After this, the screen was cleared, and a box appeared containing information about the numbers of hits and misses and the percentage of Martians destroyed.

Data preparation and analysis

Suppression ratios of the form  $a/(a + b)$  were used to index participants' behavior on the critical assessment trials. In this ratio,  $a$  represents the number of responses during the critical test stimulus and  $b$  the number of keypresses in the interval preceding  $a$ . The interval lengths of  $a$  and  $b$  were always identical. For example, on a 3-s target-alone ( $A-$ ) or feature-alone ( $X-$ ) assessment trial,  $a$  was the number of responses during the stimulus presentation and  $b$  the number of responses in the 3-s period directly preceding A or X.

However, when the feature and target were sequentially presented in a compound (e.g.,  $X \rightarrow A-$ ),  $a$  corresponded to the number of keypresses during the 3-s target A presentation, and  $b$  represented the number of keypresses during the 3-s interval immediately preceding feature X. A suppression ratio of 0 indicated complete suppression of operant responding, and hence, a strong Pavlovian conditioned response (complete absence of responding during the test stimulus), whereas a suppression ratio of 0.50 indicated complete absence of suppression (equal levels of responding during the presence and absence of the stimulus).

Since we had clear a priori hypotheses, we used planned comparisons to analyze the suppression ratios. Following Kirk (1995), mean-square-error (MSE) terms and degrees of freedom appropriate for the specific contrasts were used. Single-sample  $t$  tests were used to investigate whether a certain suppression ratio reliably differed from the no-suppression rate of 0.50. The level of significance was set at .05 throughout.

Results

Phase 1: Acquisition reminder test

After Acquisition 1 and 2 training and test, an acquisition reminder training and test were inserted. The “after acquisition” bars in Fig. 1 depict the mean suppression ratios for target A preceded by feature X, for target A alone, and for feature X alone at the acquisition reminder test for groups [B−], [B+],  $[Y \rightarrow B+/B-]$ , and  $[X \rightarrow B+/B-]$ . We observed a reliable difference in suppression to A versus to  $X \rightarrow A$ ,  $F(1, 36)=167.24$ ,  $MSE=.01$ ; for  $X \rightarrow A/A$ ,  $F(1, 9)=28.82$ , 63.45, 40.29, and 48.64,  $MSEs=.01$ , for groups [B−], [B+],  $[Y \rightarrow B$

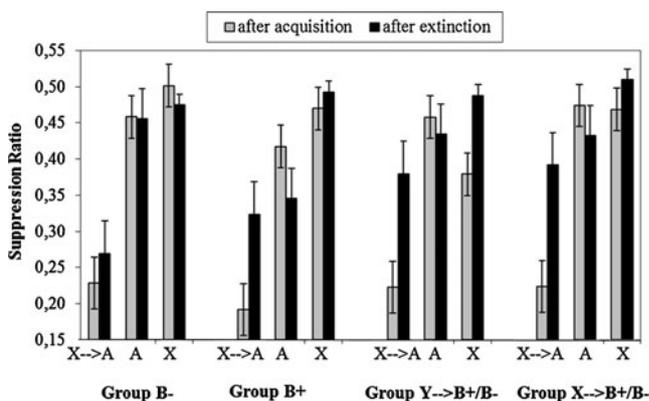


Fig. 1 Mean suppression ratios for target A preceded by feature X, target A alone, and feature X alone in groups [B−], [B+],  $[Y \rightarrow B+/B-]$ , and  $[X \rightarrow B+/B-]$ , after  $X \rightarrow A+/A-$  acquisition training in the acquisition reminder test (gray bars) and after  $X \rightarrow B-$  extinction treatment in the final test (black bars). Lower values represent more suppression, and thus stronger conditioned responding

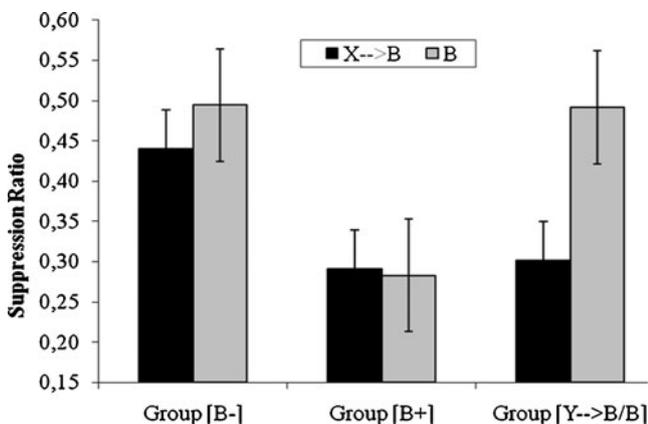
+/B–], and [X → B+/B–], respectively. There were no between-group differences in differential X → A/A responding,  $F_s < 1$ ,  $MSE_s = .005$ . Suppression to X did not differ significantly from 0.50,  $t(39) = 1.04$ ,  $p = .31$ .

We also evaluated responding to B in the acquisition reminder test phase in the different groups. We anticipated that B– trials would not lead to suppressed responding, while B + trials would. Furthermore, we predicted that Y → B+/B– and X → B+/B– acquisition training would lead to differential responding on both discriminations.

In group [B–], the mean suppression ratio for target B after B– training was .49. This suppression ratio did not differ significantly from 0.50,  $t(9) = 0.03$ ,  $p = .98$ . In group [B+], the mean suppression ratio for B after B + training was .22, which did differ significantly from 0.50,  $t(9) = 11.33$ ,  $p < .0001$ . In group [Y → B+/B–], a planned comparison revealed that participants learned to respond differentially to the Y → B+/B– discrimination,  $F(1, 9) = 15.81$ ,  $MSE = .01$ , but suppression to Y did not differ significantly from 0.50,  $t(9) = 0.62$ ,  $p = .55$ . In group [X → B+/B–], a planned comparison revealed that participants learned to respond differentially to the X → B+/B– discrimination,  $F(1, 9) = 55.29$ ,  $MSE = .005$ , and suppression to X again did not differ significantly from 0.50,  $t(9) = 0.70$ ,  $p = .50$ .

#### Phase 2: Transfer test

Figure 2 presents the mean suppression ratios for X → B and B at the transfer test (before extinction training) for groups [B–], [B+], and [Y → B+/B–]. Since acquisition in group [X → B+/B–] consisted of X → B+/B– training, nonreinforced test presentations of X → B and B actually gave an indication of trained differential responding rather than of transfer. Consequently, group [X → B+/B–] was not included in Fig. 2.



**Fig. 2** Mean suppression ratios of X → B and B in the transfer test for groups [B–], [B+], and [Y → B+/B–]. Lower values represent more suppression

**Group [B–]** Participants did not reliably differentiate between the X → B and B trials,  $F(1, 8) = 1.33$ ,  $MSE = .01$ ,  $p = .28$ , which indicates that transfer did not occur in this group.

**Group [B+]** Again, participants did not show differential X → B/B responding,  $F < 1$ ,  $MSE = .02$ , indicating that suppression to X → B, with B being an exciter, was not significantly different from suppression to B alone. In this case, however, the lack of differential responding could perhaps be attributed to the excitatory strength that target B already contained, in combination with an effect resulting in X being unable to further enhance suppression to target B (= ceiling effect).

**Group [Y → B+/B–]** These participants suppressed responding significantly more when feature X preceded target B than when target B was presented alone,  $F(1, 8) = 19.18$ ,  $MSE = .009$ .

The differences in response levels between groups [B+], [B–], and [Y → B+/B–] made it hard to compare the transfer data. That is, target B contained a large amount of excitatory strength in group [B+]. Because of this preexisting excitatory strength, X → B/B responding would be very different in this group, as compared to differential responding in groups [B–] and [Y → B+/B–], where B contained no excitatory strength.

#### Phase 3: Final test

The “after extinction” bars in Fig. 1 depict the mean suppression ratios for the X → A compound, for target A alone, and for feature X alone after the X → B– extinction treatment in groups [B–], [B+], [Y → B+/B–], and [X → B+/B–].

**Group [B–]** Differential X → A/A responding was preserved after X → B– extinction training,  $F(1, 9) = 21.11$ ,  $MSE = .008$ . Planned comparisons showed that there was no significant Moment (acquisition reminder test, final test) × Stimulus (X → A, A) interaction,  $F(1, 9) = 1.29$ ,  $MSE = .003$ ,  $p = .28$ . Suppression to X did not differ significantly from 0.50,  $t(9) = 0.92$ ,  $p = .38$ .

**Group [B+]** Differential X → A/A responding was absent after X → B– trials,  $F < 1$ ,  $MSE = .004$ ; that is, after X → B– extinction trials, participants did not suppress responding more when feature X preceded target A than when target A was presented on its own. Planned comparisons accordingly showed that there was a significant Moment (acquisition reminder test, final test) × Stimulus (X → A, A) interaction,  $F(1, 9) = 66.45$ ,  $MSE = .002$ . Suppression to X did not differ significantly from 0.50,  $t(9) = 1.10$ ,  $p = .30$ .

*Group [Y → B+/B-]* As in the previous group, discriminative X → A/A responding was absent after X → B- training,  $F(1, 9)=1.14$ ,  $MSE=.01$ ,  $p=.31$ . Planned comparisons showed that there was a significant Moment (acquisition reminder test, final test) × Stimulus (X → A, A) interaction,  $F(1, 9)=10.29$ ,  $MSE=.008$ . Suppression to X again did not differ significantly from 0.50,  $t(9)=2.06$ ,  $p=.07$ .

*Group [X → B+/B-]* As in the previous two groups, X → A +/A- discrimination was absent after X → B- extinction trials,  $F<1$ ,  $MSE=.009$ . Planned comparisons accordingly revealed a significant Moment (acquisition reminder test, final test) × Stimulus (X → A, A) interaction,  $F(1, 9)=19.04$ ,  $MSE=.006$ . Suppression to X did not differ significantly from 0.50,  $t(9)=1.15$ ,  $p=.28$ .

The change in discriminative X → A/A responding from the acquisition reminder test to the final test differed significantly between groups,  $F(1, 36)=3.28$ ,  $MSE=.015$ . A specific contrast indicated that group [B-] differed from groups [B+], [Y → B+/B-], and [X → B+/B-],  $F(1, 36)=9.6$ ,  $MSE=.005$ .

## Discussion

The aim of our experiment was to delineate the minimal conditions for the extinction of Pavlovian modulation in humans. That is, we wanted to examine whether what Rescorla (1986) found in pigeons was valid in humans as well. Namely, Rescorla (1986) found that discriminative responding in pigeons disappeared after nonreinforced presentations of a feature in conjunction with a target that differed from the one used in the original discrimination training (X → B) if that target was minimally an exciter. The results of our experiment suggest that Rescorla's (1986) conclusion on the extinction of modulation in pigeons can be generalized to humans trained in a conditioned suppression preparation.

Like Rescorla (1986), we found that discriminative responding disappeared after nonreinforced presentations of a feature in conjunction with a target that differed from the one used in the original discrimination training (X → B) if that target was minimally an exciter. This can be translated into the target having to be reinforced. An interesting further question concerns the importance of the nature of the reinforcer. Investigating what is the precise impact of using two different USs versus only one US for both initial X → A+/A- discrimination training and subsequent B training might be an interesting topic for future research. From the arguments of Rescorla (1986), one might expect that extinction and transfer would be obtained more readily if, as in the present study, the same reinforcer were used during both

training phases. Namely, according to Rescorla (1986), occasion setters have the ability to lower the threshold for activation of a specific US (and, hence, to modulate access to the US representation by the target stimuli). This idea is consistent with findings that transfer facilitation occurs across targets as long as the original and transfer targets have been trained with the same US (Davidson & Rescorla, 1986). Hence, to the extent that transfer of acquisition is a necessary precondition for extinction to occur, there would seem to be some basis for predicting that different results would be obtained in the present design following extinction treatment of a target trained with a different reinforcer versus the originally trained target. Note, however, that our own data suggest that even in the absence of any observable transfer facilitation (see group [B+],) extinction of facilitation can be obtained, such that it cannot be precluded on a priori grounds that extinction would still be possible when two different reinforcers were used.

Perhaps our results cannot be explained in terms of occasion setting, but rather in terms of deepened extinction. *Deepened extinction* (e.g., Rescorla, 2006) refers to the observation that extinction of a compound of cues may allow for a larger decrease in responding to the individual cues than would be obtained when they were extinguished separately. The default explanation for this observation entails that summation of the individual cues' expectancy values allows for more prediction error, and therefore a larger decrease in associative strength, during nonreinforcement. Crucial to this interpretation is the assumption of a threshold for the error correction mechanism of the expectancy values (or, alternatively, for evoked behavior). If this threshold value is situated above the expectancy levels of the individual cues, but below that of the compound of the cues (due to summation of the individual cues' expectancies), expectancies will not be updated on presentations of the individual cues, but they will be during compound presentations. This idea could also explain the present results, provided that one ignores the sequential ordering of the compound stimuli (i.e., if X → A+/A- training is equivalent to XA+/A- training, contrary to what is often suggested; see, e.g., Baeyens et al., 2001). During acquisition, both feature and target would then gain a subthreshold amount of expectancy, and therefore would not evoke any responding during feature- or target-alone presentations by themselves, but would evoke responding during feature-target compound presentations due to the summed feature and target expectancy values surpassing the threshold. Moreover, because the sum of X's and B's expectancy values during X → B extinction is above threshold for all groups but [B-], extinction of responding to X → A would be predicted in all groups except [B-]. Although deepened extinction has never been demonstrated in humans, a straightforward way of testing this alternative explanation would be to contrast target-target extinction (e.g., A → B-) with feature-target extinction (X → B-) after the acquisition of two different

feature-positive discriminations ( $X \rightarrow A+/A-$  and  $Y \rightarrow B+/B-$ ). Given the present observation of extinction of responding to  $X \rightarrow A$  after  $X \rightarrow B-$  training in group  $Y \rightarrow B+/B-$ , the deepened-extinction account would have to assume that X, A, Y, and B all gain subthreshold amounts of excitation, and that extinction of  $A \rightarrow B$  would also result in both A and B losing their subthreshold expectancy values, resulting in the  $X \rightarrow A$  compound no longer reaching above-threshold expectancy values in order to evoke responding. Conversely, a standard occasion-setting approach would not predict any loss of differential responding after nonreinforced presentations of a compound of targets.

Over the years, a number of models have been developed to account for occasion setting. Some of these models seem to fit the present data better than others.

According to Holland (1989a, 1989b; Lamarre & Holland, 1987), occasion setting and simple Pavlovian conditioning involve two separate memory systems. Transfer within a memory system is more likely than between systems. Therefore, a feature that acts on a higher-level control element will be more apt to act on another such element than to act on individual representations of the CS or US that occur at a lower level (Lamarre & Holland, 1987). Perhaps, like transfer, (generalization of) extinction of occasion setting is more probable within than between memory systems. This would make it possible to explain why  $X \rightarrow B-$  presentations (with B being previously modulated) extinguish the  $X \rightarrow A+/A-$  discrimination. Explaining why  $X \rightarrow B-$  extinguishes differential  $X \rightarrow A+/A-$  responding after excitatory B training, on the other hand, is more difficult. However, participants in group [B+] actually received partial reinforcement, given that target B was only reinforced 80% of the time. A partially reinforced cue may look more like a cue that was part of an occasion-setting relationship. Therefore, this partially reinforced cue might have been more ready to be represented in the same memory system as features and targets that have been modulated. However, this would also mean that transfer would be more likely. Nonetheless, feature X did not facilitate target B in group [B+] at the transfer test. As mentioned before, this lack of differential responding may perhaps be attributed to a ceiling effect.

According to Bonardi (2007; Bonardi & Ward-Robinson, 2001), an occasion setter acts on a specific CS–US relationship. Although transfer should never occur, according to this view, it is found frequently, especially to other targets that were previously involved in an occasion-setting relationship. These results can be explained by assuming that target stimuli become more similar due to their common occasion-setting training history; that is, acquired equivalence may be established between targets that have been occasion set before (Bonardi & Hall, 1994). In their model, Bonardi (2007) and Bonardi and Ward-Robinson (2001) never explored data on the extinction of modulation, but instead

focused on the transfer of occasion setting. We can speculate about what would happen when trying to extinguish an  $X \rightarrow A+/A-$  discrimination by offering nonreinforced presentations of the original feature (X) in compound with the new targets with different histories of reinforcement. Maybe nonreinforced  $X \rightarrow B-$  presentations will attenuate differential  $X \rightarrow A/A$  responding only if B was previously involved in an occasion-setting relationship. A and B might become similar due to their common training history, which may enhance the exchangeability between B and A and cause  $X \rightarrow B-$  to partially abolish the  $X \rightarrow A+/A-$  discrimination. In group [B+], however, we found that  $X \rightarrow B-$  trials also abolished the  $X \rightarrow A+/A-$  discrimination. This might have been due to the fact that B was actually partially reinforced. Hence, target B might have been functionally more like target A that had been involved in an occasion-setting relationship (in that both B and A share a history of intermixed reinforcement and nonreinforcement). However, as argued before, we would then also expect transfer to occur in this case (more suppression to  $X \rightarrow B$  than to B alone), but this was not observed. This again might be attributed to the excitatory strength that target B already contained, in combination with an effect that resulted in X being unable to further enhance suppression to target B. This lack of differential responding could (just as before) be attributed to a ceiling effect. In group [B-], where B remained nonreinforced,  $X \rightarrow B-$  presentations did not extinguish differential  $X \rightarrow A/A$  responding. From a generalization/acquired equivalence perspective, this seems highly likely, given that the training of target A was quite different from that of target B. A very different training history reduces the exchangeability between the two targets.

Pearce's (1987) configural model has already proven its worth in dealing with results from previous research on feature-positive and feature-negative discrimination learning in humans (Baeyens et al., 2001; Baeyens et al., 2004). According to Pearce (1987), the perceptual similarity between two stimuli depends on the number of elements shared, relative to the total number of elements that the compound (or element) contains. For example, during acquisition training, the  $X \rightarrow A$  compound will acquire excitatory strength due to reinforcement of the compound. This excitatory strength will partially generalize to target A, due to the perceptual similarity between target A and the  $X \rightarrow A$  compound. However, because target A is presented nonreinforced during training, it will consequently become inhibitory. In turn, some of the inhibitory strength of target A will generalize to the  $X \rightarrow A$  configuration. The amount of excitatory strength that will generalize from the  $X \rightarrow A$  compound to other elements (e.g., feature X) or to new compounds (e.g.,  $X \rightarrow B$ ) will depend on the perceptual similarity between the stimuli.

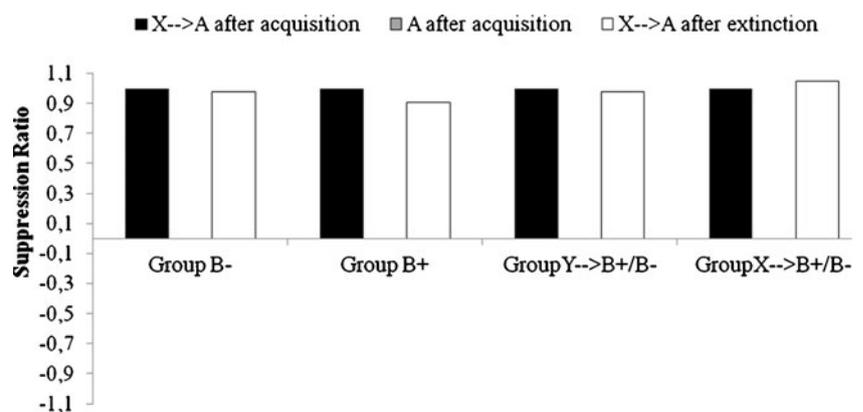
We investigated whether (and under which assumptions) Pearce's (1987) model could make correct predictions for

our experiment's extinction data. In order to do so, however, several ad-hoc assumptions had to be made, and some restrictions had to be taken into account. First, we assumed that by the end of each individual step of the experimental design (e.g., Acquisition 1, Acquisition 2, . . .), learning had reached asymptote (0 for extinction, and 1 for reinforcement), and that only learning phases, not testing or reminder phases, influenced the learning process. Second, because of the specific nature of suppression ratios, the comparisons made between the experimental and simulation results were qualitative rather than quantitative. Third, we followed Pearce's suggestion to assume that sequential presentations of the feature and the target result in the feature having a relatively lower level of salience than the target. According to Pearce's model, differences in salience can influence responding directly, by the amount of generalization (similarity) from other CSs, as well indirectly, because the amount of generalization influences how strong a CS's excitatory or inhibitory powers may become during learning. We ran the simulation three times (feature [= salience of 1] = target [= salience of 1], feature [= salience of 2] > target [= salience of 1], and feature [= salience 1] < target [= salience of 2]) in order to check whether this assumption would influence the pattern of predictions, and it did not. We found that the ordinal patterns of results were similar for all three simulations, and therefore only discuss the case of low feature and high target salience. We will point out the different sources of generalization for postextinction  $X \rightarrow A$  tests, which will allow for understanding of how the model comes to its predictions.

Our main finding concerned the occasion setters' resistance to extinction. We observed an effect of  $X \rightarrow B$ -extinction on differential responding to the originally learned  $X \rightarrow A+/A-$  discrimination in groups  $[B+]$ ,  $[Y \rightarrow B+/B-]$ , and  $[X \rightarrow B+/B-]$ , but not in group  $[B-]$ . We assumed that, after the initial  $X \rightarrow A+/A-$  acquisition training, learning reached its asymptote and suppression to  $X \rightarrow A$  was maximal, while suppression to  $A$  alone was negligible. This was identical for all four groups. Suppression to  $X \rightarrow A$  after

$X \rightarrow B$ -extinction would be determined by generalized inhibition from  $A$ , the direct excitatory powers of  $X \rightarrow A$ , and any possible generalization from  $X \rightarrow B$ . Only the amount of generalization from  $X \rightarrow B$  was different across groups (see Fig. 3). For groups  $[B-]$ ,  $[B+]$ , and  $[Y \rightarrow B+/B-]$ , the  $X \rightarrow B$ -extinction treatment will involve  $X \rightarrow B$  gaining enough direct inhibitory powers to counter its generalized excitatory powers. In group  $[B-]$ ,  $X \rightarrow B$  will get some generalized excitation from  $X \rightarrow A$ . This small amount of generalized associative strength is countered by  $X \rightarrow B$ 's own inhibition (gained during  $X \rightarrow B$  extinction treatment), which, in its turn, should decrease suppression on  $X \rightarrow A$  (and reduce differential  $X \rightarrow A/A$  responding) slightly postextinction. The predictions for group  $[Y \rightarrow B+/B-]$  are the same as those for group  $[B-]$ . That is,  $X \rightarrow B$  gets generalized excitation from  $X \rightarrow A$ , generalized excitation from  $Y \rightarrow B$ , and generalized inhibition from  $B$ . Because of this generalized inhibition from  $B$ , the generalized excitation from  $Y \rightarrow B$  will be annulled, which results in the same amount of expected suppression to  $X \rightarrow B$  and of differential  $X \rightarrow B/B$  responding as in group  $[B-]$ . In group  $[B+]$ , substantial suppression to  $X \rightarrow B$  is predicted and was observed at the acquisition test. This means that a lot of inhibition will be acquired to counter all generalized excitatory strength on  $X \rightarrow B$ . This significant inhibition will generalize to  $X \rightarrow A$  at the extinction test, resulting in slightly less suppression on  $X \rightarrow A$ , and consequently less responding than in groups  $[B-]$  or  $[Y \rightarrow B+/B-]$ . Finally, in group  $[X \rightarrow B+/B-]$ ,  $X \rightarrow B$  had already acquired excitatory powers during  $X \rightarrow B+/B-$  training. The  $X \rightarrow B$ -treatment will lower its excitatory powers, but  $X \rightarrow B$  will not become completely inhibitory, because the generalized inhibition from  $B$  outweighs the generalized excitation from  $X \rightarrow A$ . Therefore, responding to  $X \rightarrow A$  is predicted to be slightly above asymptote (= slightly less suppression), since in this condition  $X \rightarrow B$  will generalize excitation. In sum, whereas we observed postextinction differential  $X \rightarrow A+/A-$  responding in the different groups to be ordered group  $[B-] > (\text{group } [X \rightarrow B+/B-] = \text{group } [B+] = \text{group } [Y \rightarrow B+/B-])$ , Pearce's model would predict group

**Fig. 3** Associative strength according to the predictions of Pearce's (1987) configural model for groups  $[B-]$ ,  $[B+]$ ,  $[Y \rightarrow B+/B-]$ , and  $[X \rightarrow B+/B-]$ . The target salience is twice the salience of the feature. A value of 1 represents maximal associative strength, while a value of 0 indicates no associative strength. After  $X \rightarrow A+/A-$  acquisition, the associative value was maximal for  $X \rightarrow A+$  (black bars) and minimal for  $A$  (grey bars)



$[X \rightarrow B+/B-] > (\text{group } [B-] = \text{group } [Y \rightarrow B+/B-]) > \text{group } [B+]$ . A similar ordinal pattern of predictions is obtained when looking at the model's preasymptotic behavior (e.g., using ALTSim; Thorwart, Schultheis, König, & Lachnit, 2009).

If we, however, simulate the model under the assumption that the Acquisition 1 and 2 phases are trained simultaneously and intermixed—that is,  $X \rightarrow A+/A-$  mixed with  $X \rightarrow B+/B-$  training, instead of the actual  $X \rightarrow A+/A-$  followed by  $X \rightarrow B+/B-$  training. This markedly influences the outcome of the simulations. More precisely, if trained sequentially, a certain amount of the excitation gained by the  $X \rightarrow A$  configuration will generalize to  $X \rightarrow B$  during  $X \rightarrow B+/B-$  training and block learning about  $X \rightarrow B$ . After both acquisition phases,  $X \rightarrow A$  will therefore have acquired more excitation than  $X \rightarrow B$ . If trained simultaneously, both  $X \rightarrow B$  and  $X \rightarrow A$  will gain equal amounts of excitation after both acquisition phases. In this case, differential  $X \rightarrow A/A$  responding in group  $X \rightarrow B/B$  is predicted to be lowest (relative to the other experimental conditions) at the final extinction test, or highest, as we suggested. By contrasting simultaneous and sequential training of the Acquisition 1 and 2 phases, sequential training allows the  $X \rightarrow A$  configuration to acquire more excitation. For instance, under equal salience levels and simultaneous training, the acquired excitation of  $XA$  and  $XB$  is 1, and that of  $A$  and  $B$  is  $-0.5$ . However, given sequential training, the acquired excitation of  $XA$  is predicted to be 1.333, and that of  $A$  is  $-0.66$ . This is the main mechanism by which the predictions differ. If  $XA$  acquires more excitation during acquisition, differential responding at the transfer test will also be greater. Thus, it is the case that, under the assumption of simultaneous learning of both discrimination types, Pearce's (1987) model can provide more suitable predictions.

In sum, none of the aforementioned models of occasion setting can fully explain our results. More empirical work seems to be needed to further clarify the conditions under which modulation can be extinguished. Together with the present findings, such work will likely yield yet more refined theoretical accounts of the processes that govern occasion setting in humans.

**Author note** This research was supported by University of Leuven Grant GOA 3H051018 awarded to F.B. and D.H.

## References

- Arcediano, F., Ortega, N., & Matute, H. (1996). A behavioural preparation for the study of human Pavlovian conditioning. *Quarterly Journal of Experimental Psychology*, *49B*, 270–283. doi:10.1080/713932633
- Baeyens, F., & Clarysse, J. (1998). *Martians for Windows™ 95 [Computer program]*. Leuven, Belgium: University of Leuven.
- Baeyens, F., Vansteenwegen, D., Beckers, T., Hermans, D., Kerkhof, I., & De Ceulaer, A. (2005). Extinction and renewal of Pavlovian modulation in human sequential feature positive discrimination learning. *Learning and Memory*, *12*, 178–192. doi:10.1101/im.89905
- Baeyens, F., Vansteenwegen, D., Hermans, D., Vervliet, B., & Eelen, P. (2001). Sequential and simultaneous feature positive discriminations: Occasion setting and configural learning in human Pavlovian conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, *27*, 279–295. doi:10.1037/0097-7403.27.3.279
- Baeyens, F., Vervliet, B., Vansteenwegen, D., Hermans, D., Beckers, T., & Eelen, P. (2004). Simultaneous and sequential feature negative discriminations: Elemental learning and occasion setting in human Pavlovian conditioning. *Learning and Motivation*, *35*, 136–166. doi:10.1016/S0023-9690(03)00058-4
- Bonardi, C. (2007). Occasion setting is specific to the CS–US association. *Learning and Motivation*, *38*, 208–228. doi:10.1016/j.lmot.2006.08.003
- Bonardi, C., & Hall, G. (1994). A search for blocking of occasion setting using a nonexplicit training procedure. *Learning and Motivation*, *25*, 105–125. doi:10.1006/lmot.1994.1007
- Bonardi, C., & Ward-Robinson, J. (2001). Occasion setters: Specificity to the US and the CS–US association. *Learning and Motivation*, *32*, 349–366. doi:10.1006/lmot.2001.1089
- Davidson, T. L., & Rescorla, R. A. (1986). Transfer of facilitation in the rat. *Animal Learning & Behavior*, *14*, 380–386. doi:10.3758/BF03200082
- Hermans, D., Craske, M. G., Mineka, S., & Lovibond, P. F. (2006). Extinction in human fear conditioning. *Biological Psychiatry*, *60*, 361–368. doi:10.1016/j.biopsych.2005.10.006
- Holland, P. C. (1983). Occasion-setting in Pavlovian feature positive discriminations. In M. L. Commons, R. J. Herrnstein, & A. R. Wagner (Eds.), *Quantitative analysis of behavior* (Discrimination processes, Vol. IV, pp. 183–206). New York: Ballinger.
- Holland, P. C. (1989a). Acquisition and transfer of conditional discrimination performance. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 154–165. doi:10.1037/0097-7403.15.2.154
- Holland, P. C. (1989b). Feature extinction enhances transfer of occasion setting. *Animal Learning & Behavior*, *17*, 269–279. doi:10.3758/BF03209799
- Holland, P. C. (1992). Occasion setting in Pavlovian conditioning. In D. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 28, pp. 69–125). San Diego, CA: Academic Press.
- Kirk, R. E. (1995). *Experimental design: Procedures for the behavioral sciences*. Pacific Grove, CA: Brooks/Cole.
- Lamarre, J., & Holland, P. C. (1987). Transfer of inhibition after serial feature negative discrimination training. *Learning and Motivation*, *18*, 319–342. doi:10.1016/0023-9690(87)90001-4
- Miller, R. R., & Oberling, P. (1998). Analogies between occasion setting and Pavlovian conditioning. In N. A. Schmajuk & P. C. Holland (Eds.), *Occasion setting: Associative learning and cognition in animals* (pp. 3–35). Washington DC: American Psychological Association.
- Pearce, J. M. (1987). A model for stimulus generalization in Pavlovian conditioning. *Psychological Review*, *94*, 61–73. doi:10.1037/0033-295X.94.1.61
- Rescorla, R. A. (1986). Extinction of facilitation. *Journal of Experimental Psychology: Animal Behavior Processes*, *12*, 16–24. doi:10.1037/0097-7403.12.1.16
- Rescorla, R. A. (2006). Deepened extinction from compound stimulus presentation. *Journal of Experimental Psychology: Animal Behavior Processes*, *32*, 135–144. doi:10.1037/0097-7403.32.2.135
- Ross, R. T. (1983). Relationships between the determinants of performance in serial feature-positive discriminations. *Journal of*

- Experimental Psychology: Animal Behavior Processes*, 9, 349–373. doi:10.1037/0097-7403.9.4.349
- Ross, R. T., & LoLordo, V. M. (1986). Blocking during serial feature-positive discriminations: Associative versus occasion-setting functions. *Journal of Experimental Psychology: Animal Behavior Processes*, 12, 315–324. doi:10.1037/0097-7403.12.4.315
- Schmajuk, N. A., Lamoureux, J. A., & Holland, P. C. (1998). Occasion setting: A neural network approach. *Psychological Review*, 105, 3–32. doi:10.1037/0033-295X.105.1.3
- Skinner, D. M., Martin, G. M., Pridgar, A., & Van der Kooy, D. (1994). Conditional control of fluid consumption in an occasion setting paradigm is independent of Pavlovian associations. *Learning and Motivation*, 25, 368–400. doi:10.1006/lmot.1994.1019
- Thorwart, A., Schultheis, H., König, S., & Lachnit, H. (2009). ALT-Sim: A MATLAB simulator for current associative learning theories. *Behavior Research Methods*, 41, 29–34. doi:10.3758/BRM.41.1.29