Animal Learning & Behavior
2001, 29 (4), 354-366

Reversal from blocking in humans as a result of posttraining extinction of the blocking stimulus

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In a blocking procedure, conditioned stimulus (CS) A is paired with the unconditioned stimulus (US) in Phase 1, and a compound of CSs A and X is then paired with the US in Phase 2. The usual result of such a treatment is that X elicits less conditioned responding than if the A–US pairings of Phase 1 had not occurred. Obtaining blocking with human participants has proven difficult, especially if a behavioral task is used or if the control group experiences reinforcement of a CS different from the blocking CS in Phase 1. In the present series, in which human participants and a behavioral measure of learning were used, we provide evidence of blocking, using the above described control condition. Most important, we demonstrate that extinction of the blocking CS (A) following blocking treatment reverses the blocking deficit (i.e., increases responding to X). These results are at odds with traditional associative theories of learning, but they support current associative theories that predict that posttraining manipulations of the competing stimulus can result in a reversal of stimulus competition phenomena.

Responding to a stimulus that predicts an outcome can be weakened if other stimuli are presented in compound with this stimulus during training. Accounting for such stimulus competition has been central to the development of most contemporary theories of learning (e.g., Dickinson & Burke, 1996; Mackintosh, 1975; Miller & Matzel, 1988; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Van Hamme & Wasserman, 1994; Wagner, 1981). A frequently cited example of stimulus competition is the so-called *blocking* effect. Kamin (1968) showed that conditioned responding to a conditioned stimulus (CS) was diminished (blocked) if this CS (hereafter identified as X) was presented during training in compound with another CS (hereafter identified as A) that had already been established as a good predictor of the occurrence of the unconditioned stimulus (US; i.e., A–US pairings followed by AX–US pairings). The capacity to explain blocking and other stimulus competition effects separated modern formulations of the mechanisms of Pavlovian learning (e.g., Rescorla & Wagner) from previous formulations (e.g., Atkinson & Estes, 1963; Bush & Mosteller, 1951; Konorski, 1948; Pavlov, 1927).

The better-known modern theories of associative learning (e.g., Mackintosh, 1975; Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1981; hereafter identified as *traditional associative theories*) all assume that blocking occurs because the initial learning that a CS (A) predicts the US prevents the formation of an association between the added CS (X) and the US. That is, these theories assume that the blocking effect is a deficit in the *acquisition* of an association between the added CS and the US. Moreover, these theories assume that, following blocking treatment, only the actual pairings of the blocked CS with the US can counteract the blocking deficit (in theoretical terms, increase the strength of the X–US association). Other stimulus competition effects (e.g., overshadowing [Pavlov, 1927] and the relative stimulus validity effect [Wagner, Logan, Haberlandt, & Price, 1968]) are explained in a similar way by traditional associative theories. That is, they all assume that stimulus competition occurs during acquisition and that the competing CS impedes the development of an association between the added CS (X) and the US.

Contrary to the assumptions of traditional associative theories, several recently developed theories suggest that stimulus competition effects can be reversed by posttraining extinction of the competing stimulus (i.e., conditioned responding to the added CS [X] can be increased if the competing CS [A] is extinguished). There are two major

The experimental preparation and Experiments 1 and 2 were part of a dissertation submitted by F. A. to the University of Deusto in partial fulfillment of the doctoral degree. Support for this research was provided by Grants PI96/006 from Departamento de Educación, Universidades, e Investigación (Basque Government), and PB95-0440 from Dirección General de Enseñanza Superior (Spanish Ministry of Education) and by NIH Grant 33881. F. A. was supported by Fellowship BFI97.013 from Programa de Formación de Investigadores del Departamento de Educación, Universidades, e Investigación (Basque Government). We thank Mirko Gerolin, Jennifer Kelschenabch, Kerstin Kindling, Oscar Landeta, Nuria Ortega, Oskar Pineño, and Sonia Vegas for their assistance in data collection. We also thank Ralph R. Miller for enlightening discussions and for his encouragement and insightful comments on an early version of the manuscript. We are especially grateful to Ana Martínez-Pampliega for her help in recruiting participants. Finally, F. A. thanks his dissertation committee members, Imanol Amayra, Victoria Chamizo, Antonio Maldonado, Ana Martínez-Pampliega, and Ricardo Pellón, for their insights and advice relating to this project. F. A. and M. E. are now at the State University of New York at Binghamton. Correspondence concerning this article should be addressed to F. Arcediano, Psychology Department, Binghamton University, Binghamton, NY 13902-6000 (e-mail: arcedian@binghamton.edu).

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families of models that predict this effect. On the one hand, there are models based on a response rule (e.g., Denniston, Savastano, & Miller, 2001; Gallistel & Gibbon, 2000; Miller & Matzel, 1988), and on the other hand, there are models based on new learning about absent stimuli during posttraining extinction of CS (A) (e.g., Dickinson & Burke, 1996; Markman, 1989; Tassoni, 1995; Van Hamme & Wasserman, 1994). Both families of theories predict that, if the blocking stimulus is extinguished following blocking treatment, conditioned responding to the blocked stimulus will be increased.

Models based on a response rule differentiate between the process of acquisition and the production of a response. For example, Miller and Matzel (1988) assume that CS–US associations are learned through a pure contiguity mechanism and that at (each) opportunity to respond (i.e., presentation of CS X), A–US and X–US associations compete with each other to determine whether CS X will elicit a conditioned response. In general terms, these models assume that conditioned responding to a CS depends on recurring comparisons between the strength of the CS–US association and the associative strength to the US of other stimuli (discrete or contextual) that were present during training with the CS. For example, in a blocking procedure, the previously trained stimulus (A) blocks conditioned responding to the added CS (X) because A has a stronger association to the US than does X. However, if the association between A and the US is weakened (e.g., via extinction of A), the conditioned response to X should be enhanced, thereby revealing an otherwise latent association between X and the US.

Models based on new learning about absent stimuli (e.g., Dickinson & Burke, 1996; Markman, 1989; Tassoni, 1995; Van Hamme & Wasserman, 1994) were derived from traditional associative models (specifically, Rescorla & Wagner, 1972, and Wagner, 1981) and share with their predecessors the general assumption that competition between stimuli reflects a failure to acquire an association between the added stimulus (X) and the US. That is, stimulus competition is regarded as an acquisition deficit. These new models differ from the traditional models in that they posit that the associative strength of an absent stimulus may be modified if a stimulus that was previously trained in compound with the absent stimulus is subsequently presented on a learning trial. Specifically, the associative strength of a CS will increase not only when it is paired with the US, but also when both the CS and the US are expected to occur and neither of them is actually presented. According to these models, following blocking treatment, the blocked stimulus will have a weak association with the US. Subsequent extinction of the blocking CS should result in an increase in the strength of the blocked CS–US association, because both the blocked stimulus and the US are expected when the blocking CS is presented during the extinction trials (because both have previously been paired with the blocking CS) but the two of them are absent.

In summary, both the models based on a response rule and the models based on the acquisition of new learning about absent stimuli, contrary to traditional associative theories, predict that extinction of the blocking stimulus following blocking treatment should produce an increment in conditioned responding to a previously blocked stimulus. However, there have been problems in experimentally confirming this prediction, which contrasts with the successful demonstrations of increases in conditioned responding after extinction of the competing stimulus in overshadowing (Kaufman & Bolles, 1981; Larkin, Aitken, & Dickinson, 1998; Matzel, Schachtman, & Miller, 1985; Matzel, Shuster, & Miller, 1987; Wasserman & Berglan, 1998) and the relative stimulus validity effect (Cole, Barnet, & Miller, 1995). Only recently has reversal from blocking been reported in an animal study (Blaisdell, Gunther, & Miller, 1999). The primary purpose of the present paper was to assess the generality of this effect and, specifically, to determine whether it could be obtained with human participants.

The main difficulty in investigating reversal from blocking with human participants is that the blocking effect itself has proven to be quite elusive with humans (e.g., Davey & Singh, 1988; Lovibond, Siddle, & Bond, 1988; Pellón, García, & Sánchez, 1995), and the seemingly successful blocking studies have generally lacked adequate control groups, thereby being open to alternative interpretations (see Arcediano, Matute, & Miller, 1997, for a review). For example, we previously developed a behavioral preparation that proved effective in obtaining simple Pavlovian conditioning in humans (Arcediano, Ortega, & Matute, 1996), which seemingly yielded blocking (Arcediano et al., 1997), but in subsequent unpublished research with that preparation we had problems in obtaining blocking relative to a control condition in which participants were trained with a stimulus different from the blocking stimulus during the first phase of the blocking treatment (i.e., C–US trials followed by AX–US trials, with X being the target CS). Arcediano et al. (1997) used a control condition in which the *blocking* CS was uncorrelated with the US during the first phase of the blocking procedure. The uncorrelated control condition has the advantage that subjects in both the control and the experimental conditions are exposed to the same number of presentations of the blocking CS, the blocked CS, and the US. However, some studies indicate that a stimulus presented uncorrelated with the US might develop inhibitory associations (e.g., Baker, 1977; Durlach, 1986; Hearst & Franklin, 1977; Kaplan, 1984; Rescorla & LoLordo, 1965; Suiter & LoLordo, 1971; Weisman & Litner, 1969; Williams, 1986; Williams, Dyck, & Tait, 1986; Williams & Overmier, 1988), excitatory associations (e.g., Pellón et al., 1995), or simultaneous inhibitory and excitatory associations (e.g., Droungas & Lolordo, 1994; Matzel, Gladstein, & Miller, 1988) to the US. If in the uncorrelated control condition, the blocking CS acquires inhibitory properties during the first phase, this treatment could facilitate acquisition of excitatory properties by the target CS X during Phase 2 (i.e., X could become *superconditioned*; e.g., Rescorla, 1971), which could explain the apparent blocking effect in the experimental condition.

Most other studies previously reporting blocking in humans used either a control group in which the blocking CS was presented alone (i.e., without US presentations) during Phase 1 (e.g., Chapman, 1991; Chapman & Robbins, 1990) or a control group in which neither the CS nor the US was presented during Phase 1 (e.g., Pellón et al., 1995; Shanks, 1985). Both of these control groups raise problems for an ambiguous demonstration of blocking. In the former case (i.e., A-alone trials in Phase 1), the possibility exists that during Phase 2 the target CS becomes superconditioned in the control group (if some inhibition developed to A because, on the basis of the instructions to the participants, the US is expected but does not occur in the presence of A). In the latter case (no CSs or USs in Phase 1), the weak responding to the target CS observed in the blocking group could reflect habituation to the US (e.g., Pellón et al., 1995) in this group, as compared with the control group, owing to its more numerous exposures to the US.

In the present series of experiments, we examined blocking in human participants relative to a control group that received C–US pairings in Phase 1, in order to minimize the aforementioned possible confounds in the present research. This treatment is generally considered a more adequate control condition for blocking than is no treatment or uncorrelated treatment in Phase 1. Most important, we tried to determine whether extinction of the blocking stimulus after completion of the blocking treatment could result in an increment in conditioned responding to the previously blocked stimulus. Experiment 1 demonstrated behavioral blocking in humans with our preparation, with control participants receiving C–US treatment in Phase 1. Experiment 2 provided evidence of increases in conditioned responding to a previously blocked stimulus as a result of posttraining extinction of its blocking stimulus. Finally, Experiment 3 demonstrated that reversal from blocking is specific to extinction of the blocking stimulus, as opposed to extinction of any other conditioned excitor.

EXPERIMENT 1

Experiment 1 was performed to investigate whether it was possible to obtain behavioral blocking in humans, using a control condition in which a stimulus different from the blocking stimulus is reinforced in Phase 1 (see Table 1). We consider this task *behavioral* because, although there were verbal instructions explaining the task and the US was given motivational value through instructions, our dependent variable was suppression of an ongoing nonverbal behavior (i.e., barpresses on a computer's keyboard).

Method

Participants

Twenty-three undergraduate students from Deusto University (Spain) volunteered for the study. The participants were randomly assigned to either group blocking ($n = 11$) or group control ($n = 12$).

Apparatus

All the participants performed the experiment simultaneously, using personal computers, in a large room with many computers present. The participants were at least 1.5 m apart from each other, and the participants at adjacent computers received different group and stimuli assignments. Owing to the number of participants and the size of the room, three experimenters were present.

The task was a computer video game and had many features in common with the behavioral preparation described by Arcediano et al. (1996). Associative learning was evidenced in the suppression ratio of ongoing behavior (playing of a video game, during which the stimuli of a Pavlovian procedure were presented). Instead of the US's being inherently fear inducing (as with a footshock US), the US was given negative motivational value through instructions.[1]

A graphic representation of the task is displayed in Figure 1. On the computer screen, the participants saw a *jail room* with two walls, an *Exit* door composed of vertical bars, a *refuge*, a circular *figure* (with a face and arms), which the participants could make move with the cursor (arrow) keys on the computer's keyboard, and a square-shaped *response* panel. The direction of the figure's movement, which was controlled by the arrow keys, was rotated 45º from perpendicular to the participant's visual axis in order to permit the room to be shown in perspective; for this reason, a drawing showing the four cursor keys and the direction in which each key made the figure move were shown in the lower left corner of the screen at all moments. The only exit from the room was a door, initially closed, composed of 15 vertical bars. A message indicating whether the Exit door was closed or opened was displayed on the upper right corner of the screen. The goal of the participants was to escape from the room through the Exit door as many times as they could within the experimental session. They gained one point each time they escaped from the room, and the total number of points they had gained was displayed at all times during the game on the upper left and lower right corners of the screen. In order to escape from the room, the participants had to completely open the Exit door, which could be done only by making the figure press the response panel. To press the response panel, the participants had to move the figure with the cursor keys until it touched the response panel, and then the participants had to press the space bar on the keyboard to make the arms of the figure go down, thereby pressing the response panel on the monitor screen. This made the vertical bars that closed the door go up, one at a time. The door was "opened" when all 15 bars were lifted. Then, the figure could go through the door and escape from the room. Upon so doing, they earned one point and the figure was again returned to the jail room.

The Pavlovian CSs were colors displayed in two light panels that were placed on one of the walls of the jail room. When only one CS was presented, only one of the panels (which was randomly selected for each trial) displayed this CS, and the other light panel remained white. When a compound of two stimuli was presented, each panel (randomly selected on each trial) displayed a different color. All CSs were 6 sec in duration. The US consisted of the floor of the room flashing in black and white (except for the area corresponding to the refuge) cycling two times in a second. The flashing continued for

Table 1
Design of Experiment 1

Group	Phase 1	Phase 2	Test
Blocking	A–US	AX–US	X
	D–noUS	*D–noUS*	
	EF–noUS	*EF–noUS*	
Control	C–US	AX–US	X
	D–noUS	*D–noUS*	
	EF–noUS	*EF–noUS*	

Note—The letters A, C, D, E, F, and X represent different CSs. US indicates the occurrence of the unconditioned stimulus, and noUS indicates its absence. The letters representing the filler stimuli are shown in italics. See text for a description of the stimuli.

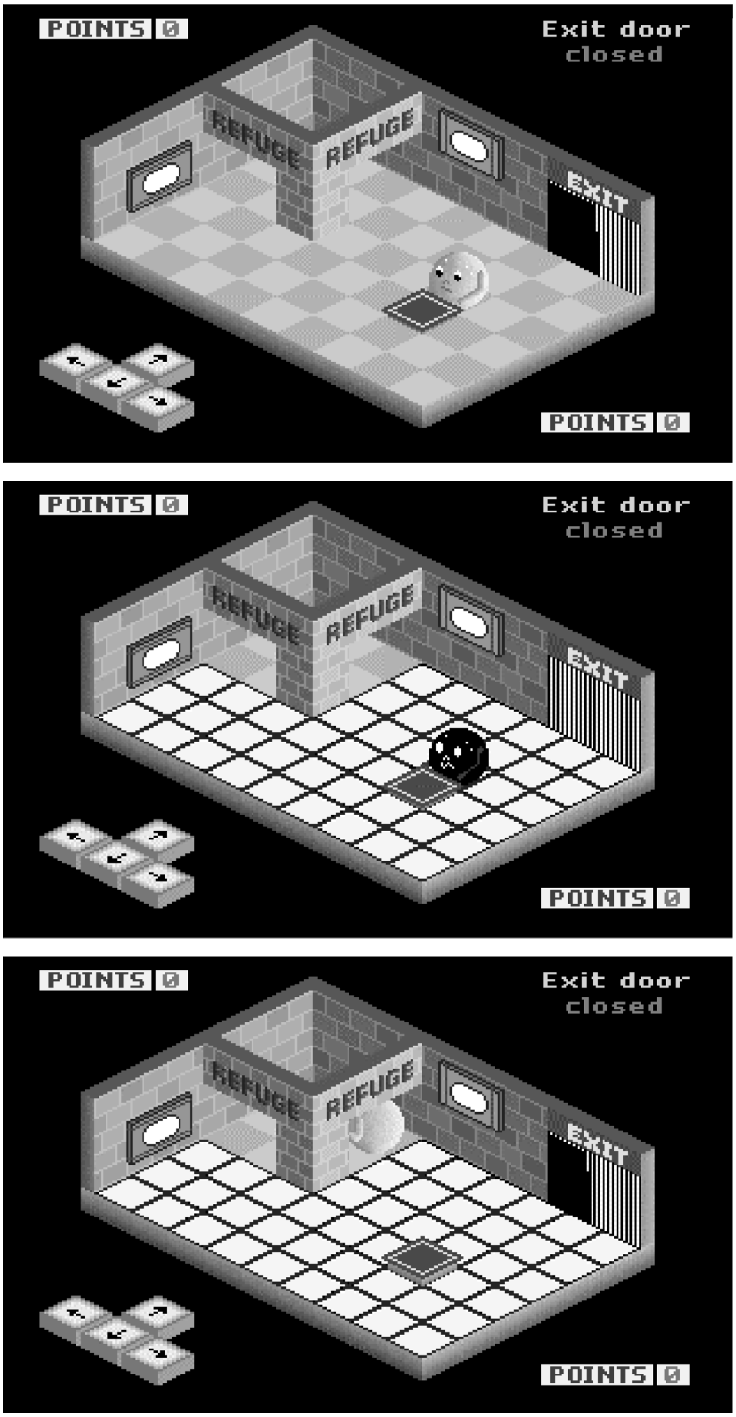

Figure 1. Screenshots of the task during training. Words on the screen were in Spanish for Experiments 1 and 2 and in English for Experiment 3. All panels show the exit door to the right, the refuge to the left, the control panel in the middle of the room, the light panels where the CSs were presented on the walls, the figure that the participants moved with the cursor keys, the score in the upper left and lower right corners, a message indicating whether the exit door was opened or closed in the upper right corner, and the directions of the cursor keys during the task in the lower left corner. The top panel presents the figure pressing the control panel to lift the bars and open the exit door. The middle panel presents the effects of US presentation while the figure is out of the refuge. The bottom panel presents successful avoidance of the US.

2 sec on each occasion. If the flashing light occurred and the figure was out of the refuge, the figure was shown flashing in black and white simultaneously with the floor, and all the vertical bars that had been lifted prior to that moment came down, one by one, closing the Exit door completely. Thus, the participants had to start lifting the vertical bars all over again when the flashing stopped. The participants could avoid this presumably aversive consequence by going into the refuge before the flashing light occurred; that is, they could avoid the closing of the partially open door if they learned to anticipate when the flashing floor (surrogate US) would occur. Thus, we expected that the participants would learn to stop pressing the space bar and go to the refuge in the presence of an effective CS (i.e., one that predicted the US). We also assumed that the participants would continue pressing the space bar in the presence of an ineffective CS (i.e., one that did not predict the US). Thereby, the suppression of the participants' pressing the space bar in order to go to the refuge was viewed as an avoidance response, which was incompatible with the ongoing response of lifting bars by making the figure press the response panel.

In our procedure, the intertrial interval was variable because it depended, in part, on the participants' behavior. A trial began only immediately after the participant pressed the space bar continuously for at least 1 sec. Then the computer recorded barpress responses during the subsequent 6 sec, with these 6 sec constituting the baseline preCS interval to be used in calculating suppression ratios. Immediately after the preCS interval had elapsed and the number of barpresses during these 6 sec had been recorded, the CSs were displayed on the light panels, and the number of barpresses during the 6 sec of CS presentation was recorded. The first second was included to increase the likelihood that the participants were pressing the space bar consistently during the 6 sec previous to the CS presentation. A further restriction was imposed on initiating trials, so that, if the participants had already opened 10 of the 15 bars constituting the Exit door, no CSs were displayed until the participant had escaped from the room and started a new round with the Exit completely closed. The reason for this restriction was that if only 5 bars remained down, the door could be opened in less than 12 sec (the sum of a preCS period and a CS period), and the participants could have stopped pressing the space bar (i.e., the response panel) during CS presentation to escape from the room, which would result in an apparent suppression of barpressing in the presence of the CS that was unrelated to the experimental design.

We used as our dependent variable a suppression ratio, which is a conventional measure in animal conditioned suppression studies (Annau & Kamin, 1961; Estes & Skinner, 1941). It was computed as $a/(a + b)$, where a was the number of barpresses during the 6 sec of CS presentation and b was the number of barpresses recorded during the immediately prior 6-sec preCS interval. A suppression ratio of zero indicates that response suppression to the CS was complete. If the CS presentation does not affect the ongoing behavior, the number of responses during the CS and during the period of time immediately preceding the CS will be similar, and therefore, the resultant suppression ratio will approach .5.

Design

Table 1 summarizes the design of Experiment 1. The participants were exposed to two phases of treatment. During Phase 1, CS A predicted the occurrence of the US in Group Blocking, whereas CS C predicted the occurrence of the US in Group Control. During Phase 2, the AX compound predicted the occurrence of the US for both groups. Finally, CS X was presented alone as a test. During Phases 1 and 2 of treatment, the participants in both groups were also presented with the nonreinforced filler Stimuli D and EF. The presentation of these filler stimuli in addition to the critical stimuli under study is a common practice in human research because, with human participants, some nonreinforced stimuli need to be included in order to prevent indiscriminate suppression to all the stimuli presented on the screen. The addition of these filler stimuli trials for both groups did not affect the relevant prediction of a between-groups difference indicative of blocking.

Procedure

Instructions. The instructions of the video game were displayed in four successive screens. An approximate Spanish-to-English translation of these instructions reads as follows:

Screen 1:

> In this experiment, you will control a person that is locked inside a room. Inside that room, you will see an Exit door composed of vertical bars, a refuge, and a response panel that you can use to lift the bars of the Exit door. You will begin the game with 0 points. Each time you get out of the room by going through the Exit door, your score will increase by one point. Your goal is to obtain as many points as you can.

Screen 2:

> In order to go out through the Exit door, you must raise all the bars in the door. To do this, you have to move the person until it is in contact with the response panel and press it with the figure's arms. To make the figure press the response panel with the arms, you have to press the space bar on your computer's keyboard. To move the figure around the room, you have to use the four cursor (arrow) keys on the keyboard. The direction of motion for each key will always be shown on the screen. If you hold down the space bar, the figure's arms will press the response panel constantly, and the bars will go up faster than if you intermittently press and release the space bar. You will not be able to go through the Exit door unless all the bars are up and the message over the door "Exit door closed" has changed to "Exit door open."

Screen 3:

> If you feel threatened at any moment, you should go to the refuge, which is the only safe place in the room. A message displayed on the screen will inform you how many points you have. Before you begin with the experiment, you will have one practice round, so that you can become comfortable with using the keyboard to move the figure around the room. After you complete this practice round, the experiment will begin.

Screen 4:

> If you have problems or questions, please do not hesitate to ask one of the experimenters. Try to get as many points as you can. Good luck! Press the space bar when you are ready to start.

Once all the participants had read the instructions on their screens, one of the experimenters emphasized the most important instructions aloud in order to make sure that they were understood. At the same time, one of the experimenters performed the pretraining phase on a large screen that could be seen by all the participants. Next, the participants performed the pretraining phase on their screens.

Pretraining phase. The participants were presented with a screen displaying the room and the figure inside the refuge. They had to move the figure around the room with the arrow keys, press down the response panel to lift the bars and open the Exit door, and escape from the room. During this phase, the light panels were not present, and no CSs or USs were displayed. Once the participants escaped from the room, a message on the screen informed them that the experiment was about to begin. To ensure that all the participants began the treatment phases at the same time, the participants could not advance to the next screen until the experimenters asked them to type a "password." During this waiting time, all questions asked by the participants were answered aloud by one of the experimenters, so that all the participants received the same information. The main purpose of the pretraining phase was to familiarize the participants with the experimental environment and teach them the basic skills required for a good performance in the video game.

Pavlovian conditioning. Immediately after completion of the pretraining phase, the participants were presented with the blocking treatment and testing. The two light panels were always displayed as white, except when CSs were presented on them. CSs and USs were superimposed on the operant task. The trial order was pseudorandomized and was the same for all the participants. The order of tri-

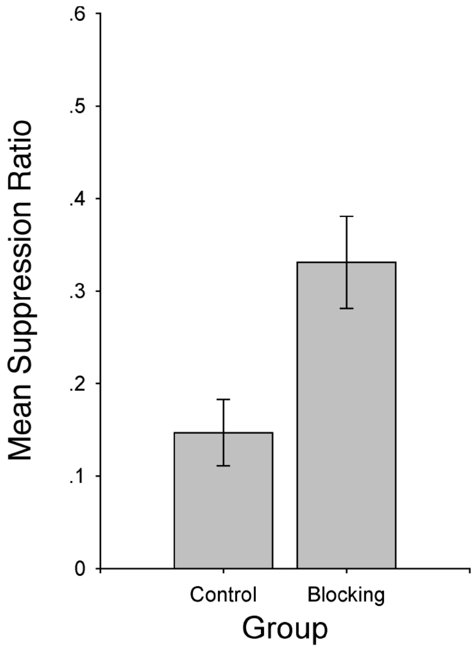

Figure 2. Experiment 1: Mean suppression ratios to the target stimulus, X, recorded during testing for both groups. Error bars represent ± *SE*.

als was A–US, A–US, D–noUS, A–US, EF–noUS, A–US, A–US, A–US, A–US, D–noUS, A–US, EF–noUS, A–US, A–US, AX–US, EF–noUS, AX–US, D–noUS, and AX–US for Group Experimental. The same sequence applied to Group Control, except that the A–US trials were replaced by C–US trials. CS duration and intertrial intervals were as described above. CSs A and C were blue, brown, or pink, counterbalanced. (Three colors were counterbalanced because, in the subsequent experiments of the series, counterbalancing of three CSs was required.) CSs D, E, and F were red, light blue, and purple, respectively. CS X was green. Testing consisted of one presentation of CS X. The training and the testing phases occurred without interruption.

We normally use a data selection criterion in order to ensure that participants have understood the instructions and are paying attention to the experiment. According to this criterion, the data from participants who do not discriminate between reinforced and nonreinforced stimuli are eliminated from the analyses. This criterion was used in Experiments 2 and 3. However, because in the present experiment we gave only two nonreinforced D–noUS filler trials (as against the 10 A–US or C–US presentations), it seemed inappropriate to take into account the data from the D–noUS trials. Thus, in this experiment, we just made sure that a good suppression of ongoing behavior was taking place when CSs A or C were presented at the end of Phase 1 (note that if the blocking CS did not produce strong conditioned suppression at the end of Phase 1, we would not expect that this CS would later block conditioning to the target CS, X). Thus, the data of participants whose suppression ratio on the last reinforced trial of Phase 1 (i.e., the last A–US trial for Group Blocking or the last C–US trial for Group Control) was greater than .3 were eliminated. Data from 2 participants of Group Blocking were eliminated following this criterion.

Results and Discussion

Figure 2 shows the suppression ratio for the target CS (X) recorded during testing. As can be seen in this figure, when CS X was presented at test, the participants in Group Blocking suppressed their barpressing behavior less than did the participants in Group Control [$t(19) = 2.59$, $p < .05$]. That is, conditioned responding to CS X was blocked in Group Blocking.

An analysis of the number of responses recorded during the 6 sec prior to the presentation of the target CS (preCS scores) revealed no differences between Groups Blocking and Control [$t(19) = 0.60$, $p > .1$]. Thus, the observed difference between groups in suppression to CS X was due to differences in suppression to CS X, rather than to their baseline responding. In addition, there were no differences in suppression ratios on the last trial of the AX compound in Phase 2 [$t(19) = 0.73$, $p > .1$]. Thus, Phase 1 treatment appears to have been the major source of the observed difference in conditioned responding to CS X at testing.

As was previously stated, we used a data selection criterion with human participants because it allowed us to eliminate data from participants that failed to exhibit suppression to a consistently reinforced stimulus for reasons unrelated to the experimental training (e.g., they did not understand the instructions, were color-blind, or did not take the experiment seriously). This criterion gave greater sensitivity to our measures, although it did not change significantly the results. Without the elimination criterion, the average suppression ratios were .14 and .33 for the control and blocking groups, respectively, a difference that still reflects the blocking deficit [$t(21) = 2.75$, $p < .05$].

The results of Experiment 1 replicated the behavioral blocking effect in humans previously reported by Arcediano et al. (1997), but with a different task and with a control group trained during Phase 1 with pairings of a stimulus different from the blocking stimulus and the US (i.e., C–US), instead of presentations of the blocking CS (A) uncorrelated with the US. The control group used in this experiment avoids many of the interpretative problems of the other control conditions mentioned in the introduction.

EXPERIMENT 2

Both the models that focus on a response rule and the models that focus on new learning about absent stimuli predict that conditioned responding to a blocked stimulus can be increased by posttraining extinction of its blocking stimulus. Thus, the prior difficulty in obtaining this effect is problematic for both families of models.

Method

In Experiment 2, two groups of participants received conventional blocking treatment, similar to that in Experiment 1. Then one of these groups received posttraining extinction of the blocking CS (Group Reversal), whereas the other group received nonreinforced presentations of a novel stimulus (Group Blocking, see Table 2). A third group of participants did not receive blocking treatment (Group Control). Blocking would be evident if conditioned responding to the target CS was greater in Group Control than in Group Blocking. Reversal from blocking would be evident if conditioned responding to the target CS was greater in the group that received extinction treatment of the blocking CS after blocking treatment (i.e., Group

Table 2
Design of Experiment 2

Group	Phase 1	Phase 2	Phase 3	Test
Control	C–US	AX–US	B–noUS	X
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		
Blocking	A–US	AX–US	B–noUS	X
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		
Reversal	A–US	AX–US	A–noUS	X
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		

Note—Group Control did not receive blocking treatment, Group Blocking received blocking treatment without posttraining extinction of the blocking CS, and Group Reversal received blocking treatment with posttraining extinction of the blocking CS. The letters A, B, C, D, E, F, and X represent different CSs. US indicates the occurrence of the unconditioned stimulus, and noUS indicates its absence. The letters representing the filler stimuli are shown in italics. See text for a description of the stimuli.

Reversal) than in the blocking group that did not receive the extinction treatment (i.e., Group Blocking).

In this experiment, we introduced some modifications into the task and the procedure, relative to Experiment 1, in an attempt to increase its sensitivity. These changes were introduced because previous attempts to reverse blocking, using the same preparation as that described in Experiment 1, had proven unreliable (we were able to find reversal from blocking, but we failed to replicate the result without these changes; see Arcediano, 1998). Our expectation was that an increase in task sensitivity would yield consistent, replicable results, which would speak to whether reversal of behavioral blocking can be obtained with human participants. There were three major changes made on the basis of several pilot studies (Arcediano, 1998). First, the number of filler trials was increased. In Experiment 1, the participants were exposed to 13 reinforced trials (i.e., 10 A[or C]–US trials in Phase 1 and 3 AX–US trials in Phase 2) and only 6 nonreinforced filler trials (i.e., D–noUS and EF–noUS [4 trials in Phase 1 and 2 trials in Phase 2]). Thus, it is possible that there was a great amount of generalized suppression toward all the presented stimuli. In order to reduce this possibility, the participants in Experiments 2 were exposed, during Phases 1 and 2, to 11 reinforced trials (8 trials in Phase 1 and 3 trials in Phase 2) and 14 nonreinforced filler trials (12 trials in Phase 1 and 2 trials in Phase 2).

The second change consisted in "punishing" all movements of the figure around the room that were not directly related to escaping from the room. Thus, unless the Exit door was completely open, any movement of the figure around the room would make the vertical bars go down slowly one at a time. In previous experiments, it was not unusual that, perhaps by excessive prudence or "fear," some participants went to the refuge when any stimulus was displayed, although some stimuli (i.e., D and EF) consistently predicted the absence of the US. We expected that, as a result of this "punishment," the participants would be more selective in deciding when to go to the refuge, enhancing the discrimination between reinforced and nonreinforced stimuli.

The third change consisted in giving the participants more explicit instructions. The participants were instructed that (1) they would see, during the task, two light panels on the walls of the room, (2) some colored lights would be displayed in these light panels on some occasions, (3) these colored lights might or might not provide information about the occurrence of a possible threat, and (4) if this threat occurred and the figure was out of the refuge, all the vertical bars that they had already lifted to open the Exit door would go down and they would lose all the effort they made toward opening the door on that round. These last changes in the instructions were expected to facilitate the participants' discrimination of the stimuli. Arcediano et al. (1996) reported that participants who received explicit instructions about the presence of stimuli that might predict the occurrence of the US during a video-game-like operant task showed faster and better discrimination of the stimuli than did participants who did not receive explicit instructions.

Participants

Sixty-four students from Deusto University (Spain) volunteered for the study. The participants were randomly assigned to Group Control (n = 20), Group Blocking (n = 19), or Group Reversal (n = 25). Variability in group size was due to the vicissitudes of scheduling.

Apparatus

The computers were identical to those used in Experiment 1, except that the computers were located in a small room, with the consequence that a small, rather than a large, number of participants performed the experiment at the same time. The experimental preparation was identical to that described in Experiment 1, except for the three changes described above. Furthermore, the two light panels on which the stimuli were displayed were smaller and located on different walls of the room and at different heights, with the purpose of discouraging configural learning of compound stimuli. In addition, the probability of any scheduled stimulus's being displayed during treatment on the left (or right) light panel was 50%, and the order of the location of each stimulus on each light panel was identical for all the participants.

Procedure

The experimental task, instructions, and pretraining phase were similar to those in Experiment 1. However, we presented the additional new instructions when the task was explained aloud to all the participants. Once the experimenter explained the task, the participants were informed that they would see, during the game, two light panels in which, sometimes, color lights were going to be displayed. Some of these colors indicated the occurrence, close in time, of an aversive event. Moreover, if this event occurred and the figure was out of the refuge, all the verticals bars lifted until that moment would go down, one bar at a time, closing the Exit door completely. The experimenter emphasized that the refuge was the only safe place in the room when this aversive event occurred and that, if the participant thought this event was going to occur, the best decision was to move the figure toward the refuge to be safe. In addition, the experimenter showed on a computer screen (which could be seen by all the participants) that unless the Exit door was completely opened, any movement of the figure around the room would make the vertical bars go down. The speed at which these bars went down while the figure was moving around the room was half of the speed at which they were lifted when the figure pressed the response panel with its arms.

Phases 1 and 2 were identical to Experiment 1, with the exception of the number of trials. In Phase 1, the participants in Groups Blocking and Reversal were presented with eight A–US pairings, eight D–noUS, and four EF–noUS presentations. The sequence of trials was D–noUS, A–US, D–noUS, A–US, EF–noUS, D–noUS, A–US, D–noUS, EF–noUS, D–noUS, A–US, D–noUS, A–US, EF–noUS, D–noUS, A–US, EF–noUS, A–US, D–noUS, and A–US. The sequence of trials was identical for Group Control, except that the A–US trials were replaced by C–US trials. In Phase 2, all the participants were presented with three AX–US, one D–noUS, and one EF–noUS trials. The sequence of trials was AX–US, D–noUS, AX–US, EF–noUS, and AX–US. In Phase 3, the participants in Group Reversal received five A–noUS presentations, whereas the participants in Groups Blocking and Control received five B–noUS presentations. Testing occurred as described in Experiment 1. Stimuli A, B, and C were blue, brown, and yellow, counterbalanced within groups. Stimuli D, E, and F were pink, light blue, and orange, respectively. The target stimulus (X) was green.

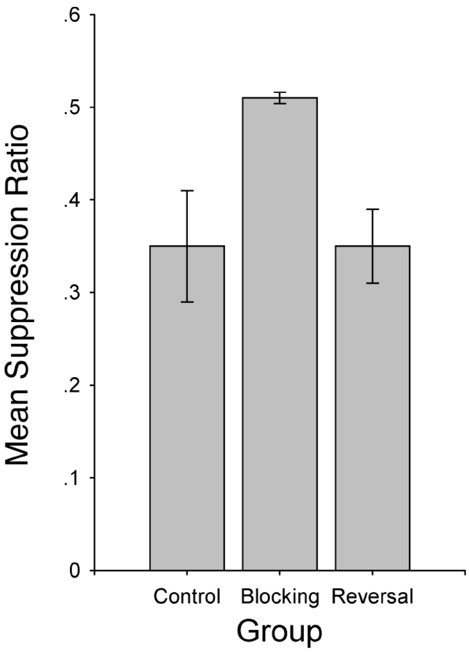

Figure 3. Experiment 2: Mean suppression ratios to the target stimulus, X, recorded during testing for each of the three groups. Error bars represent ± *SE*.

In Experiment 2, because we presented, during Phase 1, the same number of trials of a stimulus that predicted the occurrence of the US (A–US in the two blocking groups and C–US in the control group) and of a filler stimulus that did not predict the occurrence of the US (D–noUS), we were able to use the discrimination between these stimuli (one consistently reinforced and one consistently nonreinforced) as a participant selection criterion. The data from those participants that had less than a +.1 difference between the suppression ratio to the last filler trial of Phase 1 (eighth D–noUS trial) and the suppression ratio to the last reinforced trial of this Phase (eighth A–US or C–US trial) were eliminated from the analysis. We assumed that participants who did not selectively suppress their barpressing behavior to a stimulus that predicted the US, relative to a stimulus that did not predict the US, after eight trials of training with each stimulus probably did not understand the video game, did not pay sufficient attention to the experimental preparation, or had problems in discriminating between colors. A discrimination criterion appeared inappropriate in Experiment 1 because of the different number of reinforced and nonreinforced Phase 1 trials. The criterion used in Experiment 1 accepted data from all participants whose suppression ratios to the last reinforced trial of the first Phase (A–US in Group Blocking or C–US in Group Control) was less than .3; however, this criterion did not allow us to determine whether the participants suppressed their behavior selectively to stimuli that predicted the occurrence of the US or to all stimuli indiscriminately. In contrast, the criterion of Experiment 2 allowed us to eliminate data from participants who did not discriminate appropriately by the end of Phase 1. With this criterion, the data from 2 participants from Group Control, 1 from Group Blocking, and 7 from Group Reversal were not included in the analyses of Experiment 2.

Results and Discussion

The participants in Group Blocking suppressed their barpressing responses during the presentation at test of the target stimulus (X) less than did participants in Groups Control and Reversal. Therefore, the results of this experiment replicated the behavioral blocking reported in Experiment 1 and showed that conditioned responding to a previously blocked stimulus could be incremented when the blocking stimulus was extinguished following blocking treatment. Figure 3 shows the suppression ratio for the target CS (X) recorded during testing.

A one-way analysis of variance (ANOVA) performed on the suppression ratios recorded during the presentation at test of the target CS, X, yielded a main effect of group [$F(2,51) = 4.47$, $MS_e = 0.03$, $p < .05$]. Planned comparisons using the error term from this ANOVA revealed that Groups Blocking and Control differed [$F(1,51) = 7.82$, $p < .01$]. That is, conditioned suppression to CS (X) was blocked in Group Blocking. Further planned comparisons revealed that Groups Blocking and Reversal differed [$F(1,51) = 5.35$, $p < .05$]. That is, conditioned responding to the target CS (X), which had been subjected to identical blocking treatment in these two groups, was increased owing to posttraining extinction of the blocking CS (A). Moreover, there was no difference between Groups Reversal and Control [$F(1,51) < 1$]. That is, there was no difference between suppression to the target stimulus after blocking treatment plus posttraining extinction of the blocking stimulus (Group Reversal) and suppression to the target stimulus when it did not undergo blocking treatment (Group Control). Indeed, as Figure 3 shows, the mean suppression ratios to the target stimulus at test in both groups were very similar.

To test whether the differences among groups were due exclusively to the association between the target CS and the US, and not to nonassociative factors, such as differential base rate behavior, we performed a one-way ANOVA on the responses recorded during the 6 sec previous to the presentation of the target stimulus at test; this ANOVA revealed no effect of group [$F(2,51) < 1$]. Therefore, the differences between groups apparently were not due to different response rates immediately prior to presentations of the target stimulus at test. In addition, a similar ANOVA revealed no differences in the suppression ratios on the last trial of the compound AX in Phase 2 [$F(2,51) < 1$]. Thus, the differential treatments during Phase 1 appear to be the only plausible source of the observed difference in responding to CS X at test between Groups Blocking and Control. Similarly, extinction of the blocking stimulus during Phase 3 seemed to be the only plausible source of the observed difference between Groups Blocking and Reversal.

The data from all the participants (i.e., without applying the data selection criterion) were analyzed to determine whether the results reported above were an artifact of data selection. Without the use of a data selection criterion, the mean suppression ratios at test were .32, .45, and .33 for the Control, Blocking, and Reversal groups, respectively. Responding in Group Control differed significantly from that in Group Blocking [$F(1,61) = 5.59$, $MS_e = 0.03$, $p < .05$], and responding in Group Blocking differed signifi-

Table 3
Design of Experiment 3

Group	Phase 1	Phase 2	Phase 3	Test
Control	C–US	AX–US	B–noUS	X
	B–US	BY-US		
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		
Blocking	A–US	AX–US	B–noUS	X
	B–US	BY–US		
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		
Reversal	A–US	AX–US	A–noUS	X
	B–US	BY–US		
	D–noUS	*D–noUS*		
	EF–noUS	*EF–noUS*		

Note—Group Control did not receive blocking treatment, Group Blocking received blocking treatment without posttraining extinction of the blocking CS, and Group Reversal received blocking treatment with posttraining extinction of the blocking CS. The letters A, B, C, D, E, F, X, and Y represent different CSs. US indicates the occurrence of the unconditioned stimulus, and noUS indicates absence of the US. The letters representing the filler stimuli are shown in italics. See text for a description of the stimuli.

cantly from that in Group Reversal [$F(1,61) = 5.29$, $MS_e = 0.03$, $p < .05$]. In addition, we analyzed the number of points earned by participants during the experiment, which can be considered an index of stimulus discrimination and performance during the experiment. The mean number of points by participants that were and were not eliminated from the analyses were 3.80 and 6.51, respectively. This difference was statistically significant [$t(62) = 4.47$, $p < .001$].

EXPERIMENT 3

Experiment 2 demonstrated that posttraining extinction of the blocking stimulus results in an increase in conditioned responding to the previously blocked stimulus. However, one could argue that Groups Control and Blocking were exposed during Phase 3 to a neutral, novel stimulus (i.e., a stimulus without a previous history of reinforcement), whereas Group Reversal received extinction treatment with a previously reinforced stimulus. Thus, it is possible to argue that responding to the blocked stimulus (X) would be increased if a previously reinforced stimulus was presented without reinforcement in Phase 3, but not if a novel neutral stimulus was presented during Phase 3. That is, extinction of any excitor (not necessarily the blocking stimulus) might result in increased responding to X. In Experiment 3, we assessed the stimulus specificity of the reversal effect observed in Experiment 2, and we did so by extinguishing, during Phase 3, a previously reinforced, blocking stimulus in all the groups.

Method

In Experiment 3, two stimuli, A and B, were established as blocking stimuli for two targets, X and Y. After completion of blocking treatment, either A or B was extinguished, and responding to X was assessed. If the reversal effect observed in Experiment 2 is a specific result of extinguishing X's blocking stimulus, responding to X should be increased only in the group in which A was extinguished, whereas blocking should be evident in the group in which B was extinguished. If, in contrast, the reversal effect reported in Experiment 2 was the result of extinguishing any excitor after completion of the blocking treatment, blocking of X should be equally attenuated in both the group receiving extinction of A and the group receiving extinction of B (see Table 3).

Participants and Apparatus

Fifty-nine students from State University of New York, Binghamton, volunteered for the study. The participants were randomly assigned to Group Control ($n = 24$), Group Blocking ($n = 17$), or Group Reversal ($n = 18$). The computers were similar to those used in Experiments 1 and 2, and they were located in small rooms, with one or two computers per room.

Procedure

The experimental task and the instructions were similar to those in Experiment 2. However, we introduced several changes. All text was in English, all instructions were presented on successive screens on the computer (i.e., no oral instructions were given), the pretraining phase was eliminated, and the preCS interval was reduced from 6 to 3 sec. Because the number of trials was increased from 31 trials in Experiment 2 to 49 trials in Experiment 3, we decided to reduce the preCS interval in order to avoid significantly increasing the duration of the experiment. In addition, CSs were presented only if the participants were constantly pressing the space bar during the full preCS interval. Consequently, there were necessarily no differences in responding between groups (or individual participants) during the preCS interval, and all the participants were pressing the space bar when the CSs were presented. Suppression ratio was computed as $a/(a + 2b)$, where a was the number of barpresses during the 6 secof CS presentation and b was the number of barpresses recorded during the immediately prior 3-sec preCS interval.

In Phase 1, the sequence of eight A–US, eight B–US, eight D–noUS, and eight EF–noUS trials was D–noUS, A–US, EF–noUS, B–US, EF–noUS, D–noUS, EF–noUS, A–US, EF–noUS, B–US, D–noUS, A–US, EF–noUS, B–US, D–noUS, D–noUS, AUS, A–US, EF–noUS, B–US, D–noUS, A–US, EF–noUS, B–US, B–US, D–noUS, A–US, B–US, D–noUS, EF–noUS, B–US, and A–US for Groups Blocking and Reversal. The sequence of trials was identical for Group Control, except that the A–US trials were replaced by C–US trials. In Phase 2, the sequence of three AX–US, three BY–US, two D–noUS, and two EF–noUS trials was AX–US, BY–US, D–noUS, EF–noUS, AX–US, EF–noUS, BY–US, D–noUS, BY–US, and AX–US for all groups. In Phase 3, the participants in Group Reversal received five A–noUS presentations, whereas the participants in Groups Blocking and Control received five B-noUS presentations. Testing on X occurred as described in Experiment 1. Stimuli A, B, and C were blue, brown, and yellow, counterbalanced within groups. Stimuli D, E, and F were pink, light blue, and gray, respectively. Stimuli X and Y were green and orange, counterbalanced within groups.

As in Experiment 2, we used the discrimination between consistently nonreinforced stimuli and consistently reinforced stimuli at the end of Phase 1 as a criterion for retaining participants. Because there were now two consistently nonreinforced stimuli (D and the compound EF) and two consistently reinforced stimuli (A or C and B), with an identical number of trials during Phase 1, our criterion was adapted accordingly. That is, data from those participants that had less than a +.1 difference between the average suppression ratio to the two last filler trials of Phase 1 ([eighth D–noUS trial + eighth EF–noUS trial] / 2) and the average suppression ratio to the last reinforced trials of this phase ([eighth A–US (or C–US) trial + eighth

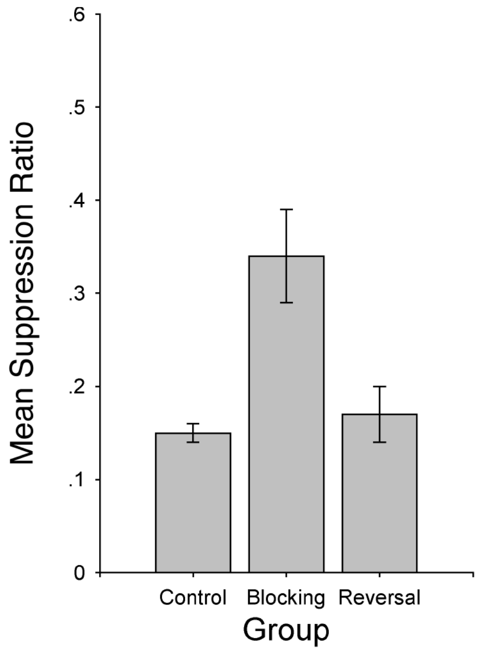

Figure 4. Experiment 3: Mean suppression ratios to the target stimulus, X, recorded during testing for each of the three groups. Error bars represent ± *SE*.

B–US trial] / 2) were eliminated from the analysis. The data from 12 participants from Group Control, 5 participants from Group Blocking, and 6 participants from Group Reversal were excluded from the analyses of Experiment 3.

Results and Discussion

Figure 4 depicts the suppression ratio for the target CS, X, recorded during testing. As can be seen, Experiment 3 replicated the results reported in Experiments 1 (blocking) and 2 (reversal from blocking). A one-way ANOVA performed on the suppression ratios recorded during the test presentation of the target stimulus (X) yielded a main effect of group [$F(2,33) = 8.15$, $MS_e = 0.02$, $p < .01$]. Planned comparisons using the error term from this ANOVA revealed that the blocking treatment was effective, as evidenced by the difference in responding to X between Groups Control and Blocking [$F(1,33) = 13.75$, $p < .001$]. In addition, there was a difference in suppression to CS X between Groups Blocking and Reversal [$F(1,33) = 10.47$, $p < .01$]. That is, conditioned suppression to the target stimulus (X) which had received a blocking treatment in both groups, was increased when the blocking stimulus (A) but not when another excitor (B) was extinguished. Finally, there was no difference between Groups Reversal and Control [$F(1,33) < 1$]. That is, there was no significant difference between the conditioned response elicited by CS X after blocking treatment plus posttraining extinction of the blocking stimulus (Group Reversal) and CS X when it had not been subject to blocking treatment (Group Control). Indeed, as Figure 4 shows, the mean suppression ratios to the target stimulus at test in both groups were very similar.

Statistical analysis on the number of responses recorded during the 3 sec prior to the presentation of X were not performed because they were necessarily identical between groups owing to the experimental preparation (i.e., CSs were presented only if the participants were continuously pressing the space bar during preCS interval). In addition, there were no differences in suppression on the last trial of the compound AX in Phase 2 [$F(2,33) < 1$]. Thus, the blocking effect (i.e., differences between Groups Blocking and Control) could plausibly be attributed only to the differential treatment in Phase 1, and the increment on the conditioned response to the previously blocked stimulus once the blocking stimulus was extinguished (i.e., differences between Groups Reversal and Blocking) could plausibly be attributed only to extinction of the blocking stimulus in Phase 3.

As in the previous experiments, the data from all the participants (i.e., without applying the data selection criterion) were also analyzed. The mean suppression ratios without application of a criterion of elimination were .22, .34, and .23 for the Control, Blocking, and Reversal groups, respectively. Responding in Group Control differed significantly from that in Group Blocking [$F(1,56) = 6.11$, $MS_e = 0.02$, $p < .05$], and responding in Group Blocking differed significantly from that in Group Reversal [$F(1,56) = 4.63$, $MS_e = 0.02$, $p < .05$]. In addition, as in Experiment 2, we analyzed the average number of points obtained by those participants whose data were and were not eliminated from the analysis. The average number of points obtained was 3.43 and 6.08, respectively. The comparison was statistically significant [$t(57) = 4.27$, $p < .001$].

In conclusion, Experiment 3 replicated the behavioral blocking observed in Experiments 1 and 2, as well as the reversal from blocking observed in Experiment 2. Moreover, Experiment 3 showed that increased responding to the previously blocked stimulus was specific to posttraining extinction of the blocking stimulus; this reversal of blocking was not observed when an excitor different from the blocking stimulus was subject to extinction treatment.

GENERAL DISCUSSION

The present series of experiments was intended to investigate whether conditioned responding to a previously blocked stimulus can be increased after posttraining extinction of the blocking CS when human participants were used in a novel behavioral task. Traditional associative theories (e.g., Mackintosh, 1975; Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1981) argue that stimulus competition is the result of a deficit in acquiring an association between the target CS and the US. Moreover, these theories posit that this deficit can be reversed only if the target CS is paired with the US in the absence of the competing CS. However, in recent years, new associative theories of acquired behavior have been developed to explain some stimulus competition effects that cannot be explained by traditional theories. One of the major predictions of these new theories is that conditioned responding to a stimulus subject to competition (e.g., overshadowing [Pavlov, 1927], relative stimulus validity [Wagner et al., 1968], or blocking [Kamin, 1968]) may be increased even if it does not receive further pairings with the US. Two families of models make this prediction. On the one hand, there are models that emphasize a response rule, and on the other hand, there are models that emphasize acquisition processes, including learning about absent stimuli.

Models based on a response rule (e.g., Denniston, et al., 2001; Gallistel & Gibbon, 2000; Miller & Matzel, 1988) assume that the relationships between the CSs and the US are learned through a contiguity mechanism. In general, according to these models, blocking can be reversed because there is an association between X and the US that remains latent and does not elicit responding because the A–US association is stronger than the X–US association (owing to the Phase 1 training). Thus, if the association between A and the US is weakened (as a result of posttraining extinction of A), conditioned responding to X will be observed. Models based on new learning about absent stimuli (e.g., Dickinson & Burke, 1996; Markman, 1989; Tassoni, 1995; Van Hamme & Wasserman, 1994) assume, as do traditional associative models (e.g., Mackintosh, 1975; Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1981), that competition between stimuli reflects a failure to acquire an association between the target stimulus and the US. However, they assume that the strength of a CS–US association will increase not only when the CS is followed by the occurrence of the US, but also when both the CS and the US are expected but not presented on a trial. Thus, during extinction of A the strength of the X–US association is assumed to increase, and responding to X should be observed.

These two groups of theories have been successful in explaining increases in conditioned responding to stimuli under competition after posttraining extinction of the competing stimulus in paradigms such as overshadowing (Kaufman & Bolles, 1981; Larkin et al., 1998; Matzel et al., 1985; Matzel et al., 1987; Wasserman & Berglan, 1998) and the relative stimulus validity effect (Cole et al., 1995). However, their prediction of reversal of conditioned responding to a previously blocked stimulus has proven difficult to confirm. Only recently did Blaisdell et al. (1999) report this effect under select conditions, using rats as subjects. In order to provide a human analogue of this elusive effect, we developed a new behavioral procedure to measure learning of associations between stimuli, using conditioned suppression of ongoing behavior as dependent variable. Our experimental preparation shared many basic ideas with the behavioral preparation developed by Arcediano et al. (1996) but attempted to provide greater experimental sensitivity, which seemed necessary to detect relatively small changes in responding that may testify to the reversal of stimulus competition. Indeed, the blocking effect itself has been quite elusive in human research (see the introduction), and it seemed quite clear that only by developing a more sensitive preparation could we investigate both blocking and reversal from blocking in humans. In Experiment 1, we replicated the blocking first reported with a nonverbal behavioral measure in humans by Arcediano et al. (1997), but here we used an improved control condition for blocking (i.e., C–US followed by AX–US). In Experiment 2, some aspects of the behavioral preparation were modified to provide greater task sensitivity, in order to observe the impact on blocking of posttraining manipulations of the blocking stimulus. Experiment 2 replicated the blocking effect obtained in Experiment 1 and reversed (i.e., increased) conditioned responding to a previously blocked stimulus as a result of posttraining extinction of its blocking stimulus. Finally, Experiment 3 demonstrated that the reversal effect observed in Experiment 2 was specific to extinction of its blocking stimulus; extinction of another previously reinforced stimulus had no effect on responding to the blocked target stimulus.

The present experimental series demonstrates that increases in responding to a blocked stimulus after posttraining extinction of the blocking stimulus can be generalized to human participants. To our knowledge, this is the first replication of the reversal from blocking owing to extinction of the blocking stimulus that was reported by Blaisdell et al. (1999) in rats. It is unclear for us why reversal of blocking in both humans and animals has been so elusive. After repeated failures to obtain increased responding to the blocked stimulus by posttraining extinction of the blocking stimulus (e.g., Miller, Schachtman, & Matzel, 1987), Blaisdell et al. reported this effect when a single-phase blocking procedure (A–US and AX–US trials interspersed) was followed by 200 extinction trials of the blocking CS (Experiments 2 and 4) and when a conventional two-phase blocking procedure was followed by 800 extinction trials of the blocking CS (Experiments 3 and 4). After many modifications of the experimental preparation and several parametric studies (Arcediano, 1998), we were able to provide a human analogue to the results reported by Blaisdell et al. Interestingly, Blaisdell et al. (Experiments 3 and 4) needed 800 extinction trials of the blocking stimulus to obtain increased responding to the blocked stimulus, whereas we (with a similar two-phase blocking procedure) required only 5 extinction trials of the blocking stimulus (Experiments 2 and 3). As Blaisdell et al. suggested, a possible account of why they needed such a large number of extinction trials would be based on the concept of biological significance (i.e., behavioral control; e.g., Denniston, Miller, & Matute, 1996; Miller & Matute, 1996). The US used by Blaisdell et al. was a footshock, a US that has proven to unconditionally control behavior in rat experiments (e.g., Denniston et al., 1996). In contrast, the US in the present experiments was not a biologically significant event; the participants lost and gained only points, events that are significant enough to produce responding but sufficiently nonaversive to be ethically acceptable in human research. We can speculate that more extinction trials are required in a preparation that uses a biologically significant US than in a preparation in which the US is of low biological significance, because reversal of stimulus competition is observed only if both responding and biological significance are extinguished to the competing stimulus.[2]

The present data support the view that posttraining manipulations of the competing stimulus (in the present case, the blocking stimulus) can result in reversal of stimulus competition phenomena. Whether such reversal reflects expression of a previously latent association (as is supported by models that emphasize a response rule) or a new-learning effect (as is suggested by theories that allow new learning about absent stimuli) is still unclear. Further experiments will have to be performed in order to determine which one of these families of models is more accurate and to illuminate the true nature of stimulus competition.

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NOTES

1. A demonstration version of this program can be downloaded from http://sirio.deusto.es/matute/software.html.

2. The concept of biological significance could also account for the greater difficulty in demonstrating reversal of blocking in animals, relative to reversal of overshadowing and the relative stimulus validity effect. In the latter paradigms, the target stimulus (i.e., the stimulus under competition) is presented with the competing stimulus during the first phase of conditioning and paired with a US that is normally food or footshock (i.e., stimuli of high biological significance); therefore, the target stimulus could acquire greater biological significance (i.e., behavioral control) than if the target stimulus is paired with the US only in a second phase of conditioning, when the competing stimulus has already acquired strong behavioral control (e.g., blocking). In the case of blocking, the competing (blocking) stimulus should be maximally effective in preventing the target (blocked) stimulus from acquiring biological significance. In supportive of this assumption, Blaisdell et al. (1999) required more posttraining extinction trials to observe reversal of blocking following a two-phase blocking procedure than following a single-phase blocking procedure (800 extinction trials and 200 extinction trials, respectively). Apparently, if the competing (i.e., blocking) stimulus has not already acquired complete behavioral control when the target (i.e., blocked) stimulus is first paired with the US, fewer extinction trials with the blocking CS are needed to reverse the blocking deficit.

(Manuscript received December 15, 2000;
revision accepted for publication June 4, 2001.)