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Blocking of Pavlovian Conditioning in Humans

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Despite the many demonstrations of blocking in animals, there is still little evidence of blocking with human subjects, which is problematic for general learning and behavior theory. The purpose of this research was to examine blocking with human subjects using a design and behavioral procedure (conditioned suppression) similar to those commonly used in animal research. First, subjects learned an operant task. Later, they were instructed to suppress responding when a visual US was presented. Two Pavlovian acquisition phases and a test phase occurred while the subjects were performing the operant task. In the first Pavlovian phase, CS A predicted the US for the experimental group, but was uncorrelated with the US for the control group. In the second Pavlovian phase, a compound CS AX predicted the US for both groups. At test, CS X was presented to all subjects and suppression ratios were assessed. Experimental subjects suppressed responding in the presence of CS X less than did control subjects, thereby demonstrating a blocking effect. This research, in demonstrating blocking in humans, adds to the known similarities in animal and human behavior.

Since Kamin described the blocking effect in 1968, this effect has been investigated primarily with rats and other nonhuman animals as experimental subjects. In a traditional blocking procedure, there are two acquisition phases. In the first phase, the experimental group is exposed to a conditioned stimulus

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(CS), A, paired with an unconditioned stimulus (US), whereas the control group is not exposed to these pairings; in the second phase, both groups are exposed to a compound of CS A and CS X, that is paired with the US; finally, subjects are tested with CS X. The outcome is that the target CS, X, which was paired with the US the same number of times for both the experimental and the control groups, produces weaker responding at test in the experimental group than in the control group. This effect, along with other stimulus selection effects (e.g., relative validity; Wagner, Logan, Haberlandt, & Price, 1968), has had a profound influence on most current theories of learning and behavior (e.g., Mackintosh, 1975; Miller & Matzel, 1988; Pearce & Hall, 1980; Rescorla & Wagner, 1972) because it proves that the response elicited by a target CS (X) is not independent of the associative status of other stimuli (CS A) that were present during training of the target CS.

The blocking effect has been well established with animals during many years of research (e.g., Kamin, 1968; Miller & Matute, in press). But only recently has blocking been reported with human subjects. Interest in blocking in humans was advanced by Dickinson, Shanks and Evenden (1984; see also Chapman & Robbins, 1990; Shanks, 1985; Williams, Sagness, & McPhee, 1994), who suggested that human causality judgments and categorization can be considered analogs of animal conditioning. From this perspective, the causes or antecedent events in human causal and categorization learning studies are frequently considered to be equivalent to CSs, and the effects or subsequent events are usually considered to be equivalent to USs. However, although we agree with this point of view, causal learning research with human subjects does not appear to be fully analogous to animal conditioning research. One important procedural difference between human causal judgment and animal conditioning research is how the dependent variable is assessed. One of the commonly used procedures in the study of conditioning in animals is conditioned suppression of an ongoing behavior (Annau & Kamin, 1961), which is a nonverbal behavioral measure. In contrast, the procedure most commonly used to measure the dependent variable with human subjects is the verbal assessment of causal judgment: once the subjects have completed the acquisition phase in which causes and effects are presented, they have to verbally indicate the probability with which they believe that an event (cause or CS) will be followed by its outcome (effect or US). The use of verbal responses (e.g., causality judgments) as a dependent variable has some problems. For example, Matute, Arcediano, and Miller (1996) reported that the manner in which the test question was worded strongly influenced the results that were obtained. Moreover, many researchers have argued that independent and dissociable learning systems may be responsible for verbal and behavioral responses. Although this is very controversial (see Shanks & St. John, 1994, for a recent review), the absence of demonstrations of blocking and other stimulus selection effects using behavioral responses with humans has sometimes been interpreted as supporting the view of a dissociation between different learning systems in the human species (e.g., Vila, 1996). The primary purpose of this research was, therefore, to investigate whether stimulus selection effects (e.g., blocking) could be obtained with humans using nonverbal behavioral responses as the dependent variable.

Some researchers have already investigated the blocking effect in humans using nonverbal procedures, such as electrodermal conditioning (Davey & Singh, 1988; Hinchy, Lovibond, & Ter-Horst, 1995; Lovibond, Siddle, & Bond, 1988; Pellón & García-Montaño, 1990; Pellón, García, & Sánchez, 1995) and eyelid conditioning (Martin & Levey, 1991). However, most of them have reported difficulties in demonstrating blocking in humans. Davey and Singh and Lovibond *et al.* reported no evidence for blocking of electrodermal conditioning. Vila (1996) found no evidence of behavioral blocking (as was also the case in several unpublished experiments conducted in our own laboratory). Martin and Levey reported no evidence of blocking of eyelid conditioning when they used a between-subjects blocking design, although they did report a blocking effect when they used a within-subjects design. Pellón and García-Montaño reported blocking of electrodermal conditioning, but their study presented some problems that allowed for alternative interpretations in terms of US habituation in the blocking group (see Pellón *et al.*). Although the problems in the study by Pellón and García-Montaño were addressed in a subsequent study by Pellón *et al.*, who showed that their effect was not due to US habituation, Pellón *et al.* also reported finding no differences between a blocking group and a control group for which the blocking CS and the US were presented in an unpaired manner during Phase 1. This unpaired control group is a common control for blocking in animal research and all instances of it of which we are aware in the human Pavlovian literature have yielded no evidence for blocking (Davey & Singh; Pellón *et al.*, 1995).

Hinchy *et al.* (1995) attributed the many failures in obtaining a blocking effect with human subjects to a difficulty of humans in integrating the three phases of the blocking procedure. Even though the three phases of blocking are usually run without interruption in the typical human experiment, humans might perceive these phases as independent experiments because Phase 1 involves elemental stimulus presentations, Phase 2 involves compound stimulus presentations, and the test phase involves the use of elemental stimuli again (see also Pellón *et al.*, 1995; Shanks & López, 1996, for similar views). This possibility prompted Hinchy *et al.* to use a single-phase design in which the trial types of the typical blocking phases were intermixed. As they noted (p. 4), ‘‘the resultant design resembled a relative validity design (Wagner, 1969).’’ By doing this, Hinchy *et al.* obtained a stimulus selection effect in human electrodermal conditioning (see also Hammerl, 1993, for a single-phase selection effect analog in instrumental learning). However, the possibility that stimulus selection effects can perhaps only be obtained in humans using single-phase designs (e.g., relative validity; Wagner, 1969) raises some questions about the traditional interpretations of stimulus selection effects and their generality to the human species. Are humans really unable to integrate the learning that CS A predicts the US during Phase 1 with the learning that the compound CS AX predicts the US in Phase 2? Do humans tend to a more configural way of learning than other animals, which prevents them from learning during Phase 2 that CS A is still present, and is still predictive (see, e.g., Pearce, 1994; Williams *et al.*, 1994, for configural views of the learning process)? These, and other potential questions, along with the many failures and difficulties to replicate traditional two-phase Pavlovian blocking in humans might suggest an important difference between animals and humans, which is contrary to the assumption of cross-species general principles made by most theories of learning. We suspect, however, that the use of physiological measures in most human Pavlovian studies creates more technical problems (e.g., very large variability, see Martin & Levey, 1991) than the behavioral methods commonly used with animals. For all these reasons, our aim was to examine blocking in humans using a more traditional design and a behavioral preparation that was recently developed by Arcediano, Ortega, and Matute (1996) to obtain behavioral assessment of human Pavlovian conditioning in a way as similar as possible to that used with animals.

OVERVIEW OF THE EXPERIMENT

One of the most common preparations used in animal research to assess whether blocking has occurred is conditioned suppression. In this procedure the dependent variable is the degree of suppression of ongoing operant responding during the presentation of the target CS. The degree of suppression can be interpreted as indicative of the degree to which the animal is expecting an aversive US to occur after the CS. Suppression is ordinarily indexed by a suppression ratio computed as $a/(a + b)$, where a is the number of responses during the CS, and b is the number of responses in a comparable period of time immediately prior to the occurrence of the CS (Annau & Kamin, 1961). A suppression ratio of 0 indicates that conditioned suppression to the CS was complete. By contrast, if no conditioning has occurred and the CS does not affect behavior, the number of responses during the CS and during the interval that immediately precedes the CS are identical, and therefore, the resultant suppression ratio is 0.5. Therefore, when this technique is used with nonhuman animals, this indirect measure of fear of US is used as a methodological tool to assess whether subjects expect the US to occur after the CS.

In the present research we used the human conditioned suppression preparation of Arcediano *et al.* (1996). Ethical constraints in the use of aversive USs with human subjects prompted Arcediano *et al.* to develop an adaptation of the suppression preparation for human subjects that uses a visual US, and which does not make use of fear in order to obtain unconditioned suppression to the US: The US is given suppression value through verbal instructions. The critical finding in Arcediano *et al.'s* study was that human subjects learned to discriminate between the CSs that predicted and those that did not

TABLE 1
Design Summary of the Pavlovian Contingency Superimposed on the Operant Task

Group	Phase 1	Phase 2	Test
Experimental	**A+**/B−	**AX+**/BY−	**X**
Control	**A−**/B−/+	**AX+**/BY−	**X**

Note. (+) Indicates the presence of the US (flashing white background on computer screen); (−) indicates absence of the US; (/) indicates explicitly unpaired events; A and B were blue and yellow backgrounds, counterbalanced; X and Y were high and low frequency complex tones, counterbalanced. The operant contingency on which this design was superimposed was constant for both groups and simply required one response every 0.2 s. The critical blocking procedure is shown in boldface. B and Y were used to prevent excessive generalization (see text).

predict the US, and reflected this learning through anticipatory suppression of ongoing responding in the presence of the predictive CSs.

In the present research, subjects first learned to barpress steadily using the space bar of a computer keyboard, and then the two phases of conventional blocking were presented while the subjects were barpressing. Finally, the target CS was presented in the test phase and suppression of barpressing was assessed. The question of interest was whether conditioned suppression to the target CS would be blocked in an experimental blocking group relative to an appropriate control group.

METHOD

Subjects and Apparatus

Thirty undergraduate students from Deusto University (Spain) volunteered for the study. They were randomly assigned to either the experimental or control group (n = 15 for each group). Subjects were run individually, using a personal computer, in a small room. The experimenter remained in the room with the subject during the pre-training phase and until the subject had read and understood the instructions for the Pavlovian phases. After that, the experimenter stayed in an adjacent room.

Design

Table 1 summarizes the design. For the experimental group, stimulus A predicted the occurrence of the US, and stimulus B predicted the absence of the US during Phase 1. For the control group, stimuli A and B, and the US, were explicitly unpaired during this phase. Phase 2 of training and the test phase were identical for the two groups. During Phase 2, a compound stimulus consisting of A and X (AX) predicted the occurrence of the US, and a BY compound stimulus predicted the absence of the US. In the test phase, stimulus X was presented to all subjects and suppression of ongoing barpressing was assessed.

CSs B and Y were distractor stimuli. They were never paired with the US. The presentation of such irrelevant stimuli in addition to the critical stimuli under study is common practice in human research, because the typical computer-based tasks used with humans are generally quite simple, and some distractor stimuli have to be included in order to prevent excessive generalization. However, the addition of these distractor stimuli does not affect the relevant predictions.

Procedure

Pre-training. The purpose of this phase was to teach each subject to bar-press consistently using the space bar of the computer keyboard. No CSs or USs were presented during this stage. This phase was identical to the baseline pre-training phase in Arcediano *et al.'s* (1996) Experiment 1. A translation of the instructions used for this phase reads as follow:

> Your task is to prevent Martians from landing. Every half second one new Martian will try to land. In order to destroy them, you must use your laser-gun (the space bar) before they can see you, that is, just before you can see them. But do not shoot too early because you only have one shot per Martian. At the end of this phase, we will tell you the percentage of Martians that you have killed. THE PLANET DEPENDS ON YOU!! DO NOT ALLOW THEM TO LAND!

''Martians'' were represented by ASCII 002 (☻) on graphics mode, on a 14-inch VGA screen with 320 × 200 pixels resolution. The Martians were approximately 7 mm in diameter. They appeared at intervals of 0.3 s on a black background. Between each Martian and the next one on the screen, there was a separation equal to twice their diameter. If subjects pressed the space bar just before a Martian was displayed, an ''explosion'' (ASCII 015 [☼], 7 mm in diameter as well), rather than another Martian, was displayed. The objective was to have a screen filled with explosions, not with Martians. Only one barpress per Martian was allowed. If more than one barpress was recorded (e.g., if subjects held down the space bar), a Martian, rather than an explosion, was printed; thus, subjects failed in their objective at that point. All this was initially demonstrated by the experimenter, who performed the first few responses and then passed the keyboard to the subject. The screen was filled with 80 figures (Martians or explosions, 10 in each of 8 lines). No breaks between screens occurred. Instead, when the screen was filled, it moved up one line at a time to make room for new Martians. One hundred Martians were depicted as attempting to land during this phase. The score (percentage of Martians destroyed by explosions) was shown at the end on a new screen, from which Martians and explosions were removed.

Pavlovian conditioning. Following pre-training, the two blocking phases and the test phase occurred. These phases were superimposed on the operant task. That is, the CSs and USs were presented during the Martian task.

The instructions used for these phases were the ones used in the Pavlovian phase of the ‘Instructed’ group of Arcediano *et al.* (1996, Experiment 2), which had produced a good learning of a simple A+/B− discrimination after just four trials with each CS (as opposed to a group receiving no instructions and taking eight trials to learn the discrimination). A translation of these instructions reads as follows:

> Now the Martians have developed a powerful anti-laser shield. You must continue using your laser to prevent their landing. BUT BE CAREFUL because, if you shoot your laser-gun when the shield is connected, your shot will reflect back to you, thousands of Martians will immediately land safely, and you will not be able to stop that invasion. You will know that the shield is connected when you see a WHITE intermittent FLASHING on the screen.
>
> Some INDICATORS will help you predict when the shield is about to be connected, but there will also be some false cues. If you learn to distinguish between the correct and the false indicators you will be able to always avoid the shield. Otherwise, each time the Martians connect their shield you will be shooting and they will successfully invade.
>
> Remember, if you make even one shot while the shield is connected (WHITE FLASHING SCREEN), the Martians will successfully invade!!

Now, Martians appeared at 0.2-s intervals (i.e., 5 Martians/s). The US was a white flashing screen (12 flashes/s) presented for 0.4 s if the subject did not barpress during those 0.4 s. But if the subjects barpressed, the flashes remained on for an additional 5-s period during which Martians invaded the screen and subjects could do nothing to stop this invasion once it had began. CSs A and B were blue and yellow backgrounds, counterbalanced. CSs X and Y were two different complex pulsed tones presented through headphones at 70 dB (A scale), counterbalanced. One of them was a low frequency complex tone consisting of a 50-Hz component followed by a 100-Hz component, with a pulse rate of 5 cycles/s. The other one was a high frequency complex tone consisting of a 2000-Hz component followed by a 1500-Hz component, with a pulse rate of 3 cycles/s. CSs duration during the two acquisition phases was 1 s, except for the last A and B trials in Phase 1 and the last AX and BY trials in Phase 2, which lasted 3 s. These longer CSs were used in order to assess suppression at the end of each training phase. The background color remained black during the intertrial intervals (ITI). The duration of of the ITI was pseudorandom with a range between 5 and 10 s and a mean of 7.5 s. Operant responses in these phases continued to be reinforced during the ITIs as well as during the presentations of the CSs. Only barpresses that occurred during the US were ‘‘punished’’ with a flood of invading Martians.

In the first phase of training, there were 16 trials for each CS, A and B, which were presented in pseudorandom order. For the experimental group, US onset always coincided with termination of CS A. For the control group, CS A, CS B, and the US were explicitly unpaired. In the second phase of training, there were 4 presentations of each compound CS (i.e., 4 AX trials and 4 BY trials) in pseudorandom order. US onset always coincided with termination of the AX compound. BY presentations were never followed by the US. The test phase occurred 15 s after the presentation of the last Phase 2 trial, while subjects were still barpressing during the Martians task. During the test phase, stimulus X (the target stimulus) was presented once to all subjects. CS duration at test was 5 s. Phase 1, Phase 2, and the test phase were presented without interruption.

RESULTS

The central finding of this study was blocking of conditioned suppression to the target stimulus (CS X). Mean suppression ratios for the blocked stimulus (X) were 0.39 (SE = 0.02) for the experimental group and 0.27 (SE = 0.04) for the control group. Control subjects suppressed more to CS X than experimental subjects during the test phase, $t(28) = 2.21$, $p < .05$, which is indicative of blocking.

Some variables in addition to suppression to X were recorded during the two phases of acquisition in order to assess whether subjects in the two groups were sensitive to the treatments to which they had been exposed. Specifically, the last trial in which the CS A was presented during Phase 1 (i.e., trial A-16) was found to elicit stronger suppression in the experimental group than in the control group, $t(28) = 3.49$, $p < .01$, and the last trial in which the AX compound was presented in Phase 2 (i.e., trial AX-4) produced equivalent responding in the two groups, $t(28) = 0.57$, $p > .5$. This former difference indicates that experimental and control subjects were sensitive to the differential treatment that they received in Phase 1, and the latter indifference given suggests equal sensitivity to the common training that the two groups received in Phase 2. Thus, our focal independent variable, treatment received during Phase 1, appears to be the source of the observed difference in conditioned responding to CS X during the test phase.

DISCUSSION

Previous failures and difficulties in demonstrating blocking of conditioned responding in humans in contrast to successful blocking in nonhuman animals could be interpreted as arising from a fundamental difference in the way humans and animals process information and respond to it, a conclusion that would be problematic for the most basic principles of generality in learning and behavior theories. However, the present research shows that a blocking effect analogous to that commonly observed in animals can also be obtained in human subjects. This finding adds support to the view that common learning and behavior processes exist between different species and suggests that previous problems in demonstrating human blocking were more of a methodological than of a fundamental nature.

This research might be regarded as the first compelling evidence of human blocking using a non-verbal assessment procedure. As mentioned in the Introduction, human blocking of Pavlovian conditioning had been previously reported only under some non-standard conditions (e.g., single-phase designs), which had led, for example, to the hypothesis that humans could have difficulties in integrating the learning of the different phases of a blocking experiment (see Hinchy *et al.*, 1995; Pellón *et al.*, 1995; Shanks & López, 1996). The present research demonstrated that this is not necessarily the case. Nevertheless, because the three phases were conducted without interruption in this research, our procedure might be regarded as one that favors the integration of the different phases. It must be noted, however, that because human experiments are usually quite short (they rarely take longer than one hour), introducing breaks between phases is unnecessary and thus, the running of the different phases without interruption is commonplace. Thus, the uninterrupted procedure was not a variable that differentiated our study from the previous ones. We do not know whether human subjects would integrate different phases if they were conducted on different days, as normally the case in animal studies. However, the present research showed that, at least under the typical uninterrupted procedure used with humans, our species tends to integrate the different phases of the experiment in a way similar to other animals.

Another investigation with humans, which we have not yet mentioned, was reported by Jones, Gray, and Hemsley (1990). They also used a nonverbal behavioral preparation to assess the blocking effect, but their study differed from ours in several respects. First, their dependent variable was the number of test trials that subjects needed in order to make five consecutive responses to the target (blocked) stimulus. Most importantly, their experimental and control groups differed in several variables in addition to the critical blocking treatment; this made their results inconclusive with respect to blocking. The main problem was that the blocked CS was presented during the test phase in compound with CSs that for the experimental group, but not for the control group, indicated the absence of the US. Thus, the impaired performance of the experimental group relative to the control group in predicting the US during the test phase could have been due to the test-companion stimuli signaling the absence of the US in the experimental group (i.e., conditioned inhibition), rather than to a genuine blocking effect.

The design that we used involved a standard between-subjects comparison and unpaired control group. As noted in the Introduction, this approach had previously been reported by Davey and Singh (1988) and Pellón *et al.* (1995), but they had failed to obtain blocking relative to the unpaired control group. The main problem that they encountered was that the unpaired control subjects tended to show little conditioning to the target stimulus. According to Pellón *et al.*, one potential explanation for that result was that the unpaired control group could have developed excitatory conditioning during the first phase of their experiment (see Droungas & Lolordo, 1994, for evidence of excitatory associations during unpaired training). If this were true, perhaps our using two, rather than one, unpaired CSs during Phase 1, might have produced a weaker excitatory conditioning for each of the two CSs in our control group as compared to the control groups of Pellón *et al.*, and of Davey and Singh. But in any case, differences between the present research and their studies are so numerous (e.g., different preparations, response systems, stimuli, ITIs, duration and magnitudes of CSs and USs) that it is not possible to attribute the differential outcome to any single factor. If we were to speculate, however, we would say that the blocking effect was observed in the present research because we used a behavioral procedure (see Arcediano *et al.*, 1996, for further details and discussion on this preparation), whereas all of the published failures to obtain human blocking had used physiological responses. As noted by Martin and Levey (1991), physiological assessment of Pavlovian conditioning is subject to a very large variability, both within- and between-subjects, which tends to obscure between-groups differences. Thus, the use of behavioral rather than physiological assessment was probably an important factor leading to the differential outcome in the present research.

It is true that our procedure was not fully analogous to the typical conditioned suppression preparation used with animal subjects because we did not use a conventional US. As noted by Arcediano *et al.* (1996), there are ethical constraints and practical problems in the use of conventional biologically significant USs with human subjects which make it necessary to use USs that are given motivational value through verbal instructions and symbolic punishment. However, the observation of conditioned suppression to CSs that predict the US but not to those that do not predict the US (see Arcediano *et al.*) replicates the basic finding of suppression studies with animal subjects in which the suppression initially elicited by an aversive US is transferred to a CS that predicts the occurrence of the US. The present observation of human blocking with this preparation demonstrates the potential of this technique to produce learning phenomena beyond the acquisition of conditioned responding reported by Arcediano *et al.*

In spite of some limitations due to the US used in the present research not being biologically significant, we believe that this type of preparation with conditioned suppression as a dependent variable provides a reliable methodology for the study of blocking and other Pavlovian phenomena that is simpler and more convenient than most conventional psychophysiological preparations. Moreover, it is free of some of the problems frequently observed when verbal reports are used as dependent variables. We think that verbal reports can be of value in the study of causal judgment in humans, but the use of nonverbal dependent variables reduces many problems raised by verbal assessment in the study of basic learning mechanisms. Moreover, behavioral assessment more readily permits generalization of findings with animal subjects to investigations with human subjects and vice-versa.

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