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The Relative Activation of Associations Modulates Interference between Elementally Trained Cues

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Matute and Pineño (1998a) showed evidence of interference between elementally trained cues and suggested that this effect occurs when the interfering association is more strongly activated than the target association at the time of testing. The present experiments tested directly the role of the relative activation of the associations in the effect of interference between elementally trained cues. In three human experiments we manipulated the relative activation of the interfering and target associations in three different ways: (a) introducing a retention interval between training of the interfering association and the test trial (Experiment 1); (b) training the target and the interfering associations in a single phase, instead of training them in separate phases (Experiment 2); and (c) introducing, just before testing, a novel cue which, like the retention interval used in Experiment 1, had the purpose of separating the interfering trials from the test trial (Experiment 3). All three manipulations led to an enhancement of responding to the target association at testing, suggesting that they were effective in preventing the interfering association from being the most strongly activated one at the time of testing. Taken together, these results add further evidence on how the relative activation of associations modulates interference between elementally trained cues.

Compound training between two or more cues has been regarded by traditional theories of learning as a necessary condition for cue interference to occur. Cue interference is said to occur when the acquisition of an association between a cue and an outcome interferes with the acquisition (e.g., Rescorla & Wagner, 1972) or the expression (e.g., Miller & Matzel, 1988) of

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the association between another cue and the same outcome. According to traditional associative theories (e.g., Mackintosh, 1975; Miller & Matzel, 1988; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1981), cue interference can only occur if the two cues receive compound training.

However, recent studies by Matute and Pineño (1998a) have shown evidence of cue interference in the absence of compound training. In those experiments, two cues, A and X, were separately paired with the same outcome in different phases. The basic design was similar to that of a blocking experiment except that the two cues did not receive compound training. That is, in the forward interference condition, participants received A → O training (i.e., A followed by the outcome) in Phase 1 and X → O training (instead of the typical forward blocking treatment consisting of AX → O pairings, see Kamin, 1968) during Phase 2, and they were tested on X. The order of phases was reversed in the backward interference condition (i.e., X → O, then A → O, then test on X). The results showed that A → O training given after X → O training (i.e., backward condition) led to impaired responding to X in the subsequent test phase, as compared to appropriate control groups. This result is analogous to backward blocking (Shanks, 1985), except that X and A had not received compound training. This effect did not occur when the A → O pairings occurred before the X → O pairings (i.e., forward condition). Thus, interference between elementally trained cues took place in a condition which was analogous to backward blocking, but not in the condition analogous to forward blocking. Experiments 1 and 2 of Matute and Pineño also showed that: (a) this effect was not an artifact produced by the retention interval, because exposure to the experimental context during the second phase did not lead to impaired responding to X; and (b) the effect was not due to memory overload, because it did not occur when A was not followed by the outcome (i.e., A → no O) or when the A → O pairings were given in a different context.

Those results cannot be explained by traditional theories because, as previously mentioned, all of them assume that only cues that receive compound training can interfere with each other. Moreover, even if one assumes that the common context in which A and X are trained plays the role of a compounded cue which allows interference to take place, traditional theories such as, for example, Rescorla and Wagner's model (1972) predict that the effect should be observed in the forward, rather than in the backward, condition. The reason is that according to these theories, training the interfering cue during Phase 2 (i.e., once the training with the target cue has finished) has no effect on the associative status already acquired by the target cue, because this cue is no longer present in the training trials of Phase 2. (According to Miller and Matzel's model (1988), the order in which the cues are trained is not critical because interference is assumed to take place during the test phase, but in this case interference should have been observed in both the backward and the forward conditions.)

However, there are some recent revisions of Rescorla and Wagner's model (Van Hamme & Wasserman, 1994), and of Wagner's (1981) SOP model (Dickinson & Burke, 1996), that predict that new learning can occur for a cue that is no longer present. Thus, in their Experiment 3, Matute and Pineño (1998a) systematically manipulated the training and testing contexts in order to assess whether these revised theories could account for the effect of interference between elementally trained cues. If the A → O pairings of Phase 2 occur in the same context in which X was trained during Phase 1, these theories could explain the effect by assuming that the common context can activate a representation of X during the A → O pairings of Phase 2 (in which X is absent), and this would result either in the unlearning of the X–O association (Van Hamme & Wasserman) or in the formation of an inhibitory X–O association that would thereafter interfere for behavioral control with the previously acquired excitatory association between X and O (Dickinson & Burke). In either case, these two revised models would predict weak responding to X at test if X and A were trained in the same context (i.e., the A → O training context can only activate the representation of X if it is the same context in which X was trained). The results of Matute and Pineño (Experiment 3) did not support this view. Instead, responding to X was impaired when its testing occurred in the context in which the A → O pairings had occurred, regardless of whether A and X had been trained in the same or in different contexts. This suggests that unlearning of the X–O association or the formation of an inhibitory X–O association during the interfering phase is not responsible for the observed effects. Moreover, recent research by Ortega and Matute (in press) has shown that interference occurs even when only one interfering trial is given during Phase 2, which is also contrary to the idea that the X–O association is unlearned during the interfering trials or that an opposite, inhibitory association acquired during those trials is responsible for the observed interference.

Instead, because it is the test context that needs to be identical to the context in which the A–O association is learned for interference to take place, and because one interfering A–O trial is sufficient to create interference, those results suggest that interference between elementally trained cues occurs at the retrieval stage. As a tentative hypothesis to explain this effect, Matute and Pineño (1998a) suggested that it occurs when two cues are associated to the same outcome and the interfering association is more strongly activated at the time of testing than the target one, thus preventing the target cue from controlling behavior.

The purpose of the present experiments was to provide a direct test of the role of the relative activation of the associations on the effect of interference between elementally trained cues. As in the experiments of Matute and Pineño (1998a), the associative strength of X and A will be kept identical. Thus, any difference observed in response to the target cue (X) will be due to differences in the activation of the X–O association relative to the activation of the A–O association at the time of testing.

EXPERIMENT 1

As previously mentioned, according to Matute and Pineño (1998a, 1998b), interference should be observed whenever A and X predict the same outcome and the A–O association is more strongly activated at testing than the X–O association. Thus, a direct test of this hypothesis would be to manipulate the time in which the A → O trials are given with respect to the test trial: A → O trials adjacent to the test trial or separated from the test trial with a retention interval should have differential effects on responding to X at test. Thus, in this experiment, which is analogous to an experiment by Chandler (1993, Experiment 3), we manipulated the proximity of the A → O trials to the test trial. For this purpose, we used two groups that received pairings of X and A with the same outcome in different phases (groups SO, same outcome) but differed in whether the retention interval was located between the two training phases (group SO) or between training and testing (group SO-Interval). Thus, although in both groups the A → O trials occurred after the X → O trials, we expected to replicate the interference effect in group SO but not in group SO-Interval, because in the later group the A–O association should no longer predominate after the retention interval. For this reason, a third group (i.e., group DO (Different Outcome), because X and A predicted different outcomes) was also exposed to the retention interval between the two training phases, as was group SO, but it received A → no O training during Phase 2 instead of A → O training, thus serving as a control for the effect of interference between elementally trained cues that we expected in group SO.

In previous experiments, the basic interference effect was observed in groups that were analogous to group SO as compared to groups that were analogous to group DO (see Matute & Pineño, 1998b, for a review), except that those groups were not exposed to a retention interval between the two training phases. However, the basic interference effect should still be replicated in group SO in this experiment if, according to our hypothesis, it is the proximity between the interfering trials and the test trial that produces interference. Thus, the retention interval was inserted between the two training phases in groups SO and DO in order to equate the duration of the treatment that they received to the duration of treatment in the group SO-Interval, which should not show the interference effect. A similar experimental design was employed by Rescorla (1996b, 1997) in studies of spontaneous recovery after extinction. This design has the advantage of controlling for the amount of time that elapses from the training with X until the testing, avoiding response changes due to the passage of time.

Method

Participants. Thirty-five undergraduate students from Deusto University volunteered for the study. Random assignment of participants resulted in 11 participants in group SO, 12 participants in group DO, and 12 participants in group SO-Interval.

Apparatus and procedure. The experiment was run using personal computers. The computers were located in a laboratory that allowed for the simultaneous running of five participants at a time in individual cubicles.

Matute and Pineño (1998a) had used in their experiments a preparation developed by Arcediano, Ortega, and Matute (1996) for human learning research that consists of a Martians video game in which the experiments are superimposed. In order to make sure that the effect of interference between elementally trained cues described by Matute and Pineño was not an artifact of the use of the Martians program, we here developed a whole new preparation in which the effect could be tested, thus allowing for a greater generality of the observed results. In this preparation, the task of the participants was to rescue a group of refugees by helping them to escape from a war zone in several trucks. A translation of the instructions from Spanish reads as follows:

> *Screen 1*
>
> Imagine that you are a soldier for the United Nations. Your mission consists of rescuing a group of refugees that are hidden in a ramshackle building. The enemy has detected them and has sent forces to destroy the building . . . But, fortunately, they rely on your cunning to escape the danger zone before that happens.
>
> You have several trucks for rescuing the refugees, and you have to place them in those trucks. There are two ways of placing people in the trucks:
>
> (a) Pressing the space bar repeatedly, so that one person per press is placed in a truck.
>
> (b) Maintaining the space bar pressed down. In such manner, you will be able to load people very rapidly.
>
> If you rescue a number of persons in a given trip, they will arrive at their destination alive, and you will be rewarded with a point for each person. You must gain as many points as possible!
>
> *Screen 2*
>
> But . . . your mission will not be as simple as it seems. The enemy knows of your movements and could have placed deadly mines on the road. If the truck hits a mine, it will explode, and the passengers will die. Each dead passenger will count as one negative point for you.
>
> Fortunately, the colored lights on the SPY-RADIO will indicate for you the state of the road. The lights can indicate that:
>
> (a) The road will be free of mines. → The occupants of the truck will be liberated. → You will gain points.
>
> (b) The road will be mined. → The occupants of the truck will die. → You will lose points.
>
> (c) There are no mines, but the road is closed. → The occupants of the truck will neither die nor be liberated. → You will neither gain nor lose points: You will maintain your previous score.
>
> *Screen 3*
>
> At first, you will not know what each colored light of the SPY-RADIO means. However, as you gain experience with them, you will learn to interpret what they mean.
>
> Thus, we recommend that you:
>
> (a) Place more people in the truck the more certain you are that the road will

> be free of mines (keep the space bar continuously pressed down ONLY if you are completely sure that there are no mines, because in this way you will put a lot of people in the truck. . .).
> (b) Introduce fewer people in the truck the more certain you are that the road is mined.

After these instructions, participants were shown a fourth screen that gave instructions about contextual changes. Although contextual changes are not being used in the present series of experiments, in order to avoid making more changes than necessary between different experimental series conducted with the same preparation, we maintained the four instructional screens of this program. A translation of the fourth screen reads as follows:

> *Screen 4*
> Finally, it is important to know that your mission may take place in several different towns. The colors on the SPY-RADIO can mean the same or a very different thing depending on the town in which you are. Thus, it is important to pay attention to the message that indicates the place in which you are. If you travel to another town, the message indicating the name of the town will change. When a change of destination is occurring, you will read the message ‘‘Traveling to another town,’’ so you will be continuously informed about such changes. Nevertheless, sometimes you might end up returning to the same town even if you have seen the message that indicates that you are travelling. Do not worry if all this looks like very complex at this point. Before we start, you will have the opportunity to see the location of everything (radio, town name, messages, scores, etc.) on the screen, and to ask the experimenter about anything that is unclear.

A ‘‘spy-radio’’ was used to present the cues that predicted the outcomes. Cues X, A, and C were blue, red, and green lights in the Spy-Radio, counterbalanced. Cue duration was 3 s. During the intertrial intervals (ITI), the lights were turned off (i.e., gray). The ITI duration was pseudorandom with a range between 3 and 7 s, and a mean of 5 s. In each trial, each response (i.e., pressing the space bar once) that occurred while a light was on placed one refugee in the truck. If the participant maintained the space bar pressed down while the light was on, up to 10 refugees per second could be placed in the truck in the present experiment (due to equipment change, in Experiments 2 and 3, up to 30 refugees per second could be placed in the truck, see below). In each trial, the termination of the cue coincided with the onset of the outcome.

Outcome 1 (O_1) consisted of (a) the message ‘‘[*N*] refugees safe at home!!!’’ (with [*N*] being the number of refugees introduced in the truck during the cue presentation) and (b) gaining one point for each refugee who was liberated. Outcome 2 (O_2) consisted of (a) the message ‘‘[*N*] refugees have died!!!’’ and (b) losing one point for each refugee who died in the truck. No-outcome (no O) consisted of (a) the message ‘‘Road closed’’ and (b) maintaining the previous score. Outcome messages were presented for 3 s.

TABLE 1
Design Summary of Experiment 1

Group	Treatment: Phase 1	Treatment: Phase 2	Treatment: Phase 3	Test
SO	$X \rightarrow O_1$, $C \rightarrow O_2$	—	$A \rightarrow O_1$	X
DO	$X \rightarrow O_1$, $C \rightarrow O_2$	—	$A \rightarrow$ no O	X
SO-Interval	$X \rightarrow O_1$, $C \rightarrow O_2$	$A \rightarrow O_1$	—	X

Note. A and X were the critical cues. C was included to prevent strong cue generalization. These cues were blue, red, and green colors, counterbalanced. Presentations of X were always followed by Outcome 1 (O_1), whereas presentations of C were always followed by Outcome 2 (O_2). Presentations of A were followed by O_1 in groups SO and SO-Interval, whereas they were followed by no outcome in group DO. Retention intervals (—) consisted of exposure to a black background with a message indicating that there was time to have a rest (i.e., no cues or outcomes were presented during those intervals).

The number of refugees that participants risked taking into each truck was our dependent variable. Presumably, the more certain they were that the trip would be successful, the greater the number of refugees they would take, whereas the more certain they were that the truck would explode, the smaller the number of refugees they would take.

One score panel on the screen provided information during the experiment. The panel showed the number of people that the participant was introducing into the truck on each trial. Although bar presses that occurred while the outcome message was present had no consequences, this panel remained visible during the presentation of the outcome and showed the number of people that had been boarded while the cue was present. At the termination of the outcome, this panel was initialized to 0, and responses that occurred during the ITIs were not reflected in the panel, (i.e., responses during the ITI had no consequence). Only responses which were given while a cue was presented resulted in refugees traveling in the truck and participants gaining or losing points if the cue was followed by O_1 or O_2.

Table 1 summarizes the design for this experiment. During Phase 1, all groups were exposed to identical treatment: 15 presentations of cue X, which was always followed by O_1 (i.e., $X \rightarrow O_1$), interspersed with 15 presentations of cue C, which was always followed by O_2 (i.e., $C \rightarrow O_2$). Presentations of $C \rightarrow O_2$ trials were included in order to prevent cue generalization that would result in strong responding appropriate to O_1 to all cues. In Phase 2, group SO-Interval was exposed to 15 presentations of a different cue, A, predicting O_1 (i.e., $A \rightarrow O_1$). By contrast, groups SO and DO were exposed to no cue or outcome during Phase 2. Instead, they were exposed to a retention interval that was equivalent in duration to the 15 trials being received by group SO-Interval during this phase (i.e., 195 s). During this time, the screen showed the following message for groups SO and DO:

> You now have a chance to have a rest!!!
> When this black screen disappears you will be allowed to continue your mission as you have been doing up to now.

During Phase 3, group SO was exposed to 15 presentations of cue A, predicting O_1 (i.e., A $\rightarrow$ O_1), and group DO was exposed to 15 presentations of cue A, predicting no outcome (i.e., A $\rightarrow$ no O). By contrast, group SO-Interval was exposed to no cue or outcome during Phase 3. Instead, this group was exposed to a retention interval equivalent in duration to the 15 trials received by groups SO and DO (i.e., during the 195 s of Phase 3, group SO-Interval was exposed to the message that indicated the chance to have a rest, as was the case for groups SO and DO during Phase 2). Finally, all groups received one test trial with X, followed by no O. The different phases of the experiment were separated from each other by regular ITIs, that is, they were presented without interruption except for the retention intervals explicitly mentioned in the experimental design (when the retention intervals were over, the black message screen was cleared and the participants returned to the main screen of the game for a regular ITI before the next trial was presented).

Preanalysis treatment of the data. We normally use a data selection criterion in order to ensure that participants are paying attention to the experiment and have acquired the discrimination during Phase 1. According to this criterion, the number of responses given to X during the last trial in which it is presented during training has to be higher than the number of responses given to the last trial of C. Following this criterion, no participant was eliminated from this experiment.

Results and Discussion

Training. The top panel of Fig. 1 shows the mean number of responses given to X, C, and A during training, in blocks of 5 trials. With respect to Phase 1 discrimination training, a 3 (Group: SO vs DO vs SO-Interval) $\times$ 2 (Cue: X vs C) $\times$ 3 (Block of Trials) ANOVA revealed an overall effect of Cue, $F(1, 32) = 1002.36$, $p < .01$, and of Block of Trials, $F(2, 64) = 81.78$, $p < .01$, as well as a Cue $\times$ Block of Trials interaction, $F(2, 64) = 85.69$, $p < .01$, and no other main effects or interactions. This suggests that all groups learned to discriminate between cues X and C.

The top panel of Fig. 1 also shows that groups SO-Interval and SO did not differ on their responding to A in the last block of trials (of Phase 2 and 3, respectively), and that both groups responded more strongly to A than did group DO, which received A $\rightarrow$ no O instead of A $\rightarrow$ O trials. A 3 (Group) $\times$ 3 (Block of Trials) ANOVA confirmed these impressions, by revealing an overall effect of Group, $F(2, 32) = 18.39$, $p < .01$, and of Block of Trials, $F(2, 64) = 18.70$, $p < .01$. The Group $\times$ Block of Trials interaction was not significant, $p > .05$. Pairwise comparisons showed that responding in the last block of trials of A was weaker in group DO as compared to groups

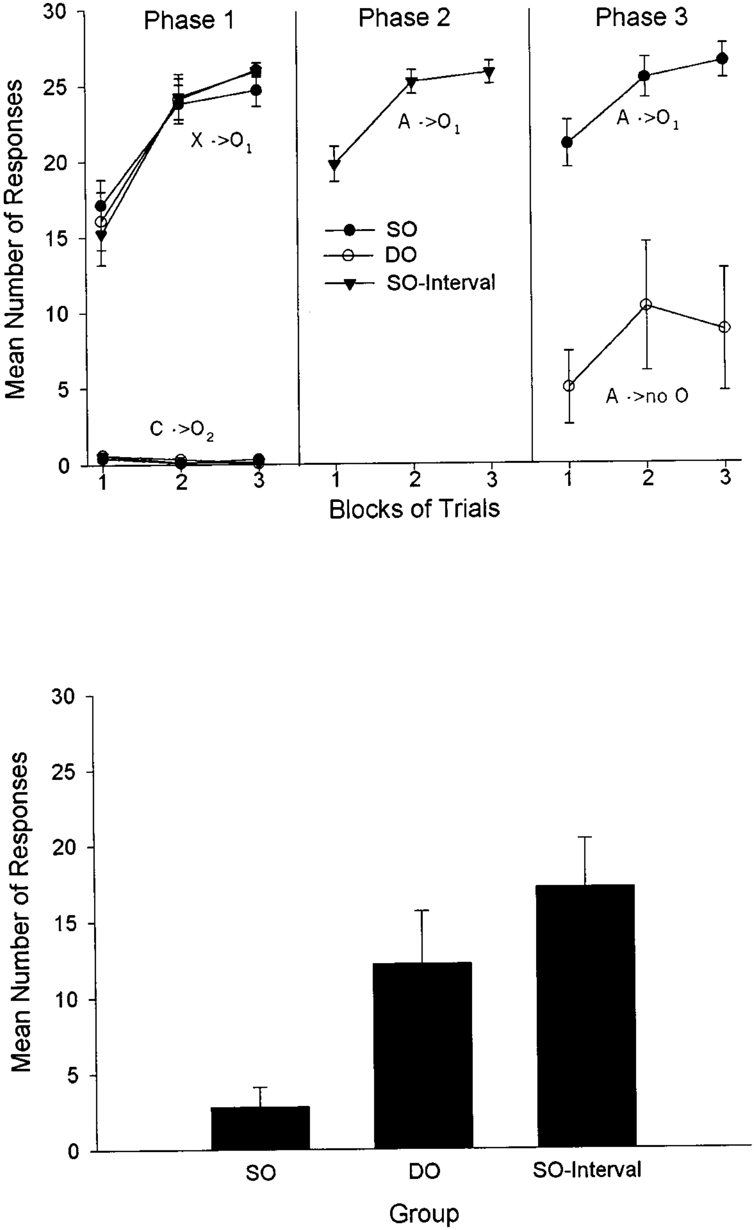


FIG. 1. Experiment 1. Mean number of responses to X, A, and C during training, in blocks of 5 trials (top panel), and to X during the test trial (bottom panel). Training with A took place in Phase 3 for groups SO and DO, and in Phase 2 for group SO-Interval. Error bars represent standard error of means.

SO, $F(1, 32) = 24.15$, $p < .01$, and SO-Interval, $F(1, 32) = 23.32$, $p < .01$, which did not differ from each other, $p > .05$. Thus, all three groups behaved according to the treatment that they received during the training phases.

Testing. The main results of this experiment are presented in the bottom panel of Fig. 1, which shows the mean number of responses to X at test. As can be seen in this figure, responding to X in group SO was weaker than in group DO, which shows that interference between elementally trained cues was replicated even though a retention interval was inserted between the two training phases in these two groups and a different preparation and dependent variable from that used by Matute and Pineño (1998a) were used. Most importantly, group SO-Interval showed greater responding to X at test than did group SO, thereby suggesting that the introduction of the retention interval between Phase 2 and testing alleviated the interference effect that was otherwise observed. This adds support to the view that interference occurs at the retrieval stage when the A–O association is more strongly activated at testing than the X–O association. Preventing the A–O association from being strongly activated at testing alleviates the interference effect. A one-way ANOVA on the test of X confirmed these impressions by showing an overall Group effect, $F(2, 32) = 6.2$, $p < .01$, and pairwise comparisons showed that responding in group SO was weaker than in groups DO, $F(1, 32) = 5.14$, $p < .05$, and SO-Interval, $F(1, 32) = 12.13$, $p < .01$, which did not differ from each other, $p > .1$. Thus, the differences in responding to X found in this experiment appear to be due to differences in the activation of the A–O_1 association at the time of testing.

EXPERIMENT 2

The results of Experiment 1 add support to the hypothesis of Matute and Pineño (1998a), according to which, in order to interfere with the target association (X–O_1), the interfering association (A–O_1) needs to be more strongly activated during testing. In Experiment 1, we manipulated the temporal location of the $A \rightarrow O_1$ trials with respect to the test trial and observed that interference occurred only when the test trial was given immediately after the interfering trials. In the present experiment we did not use retention intervals. Our purpose was to provide further assessment of that hypothesis by using a different manipulation. We compared a group in which the A–O_1 association should be the most strongly activated one during testing (i.e., a group which was analogous to group SO in Experiment 1, except that it received no retention interval, like in previous research) with a control group also equivalent to that used in Experiment 1 (i.e., group DO), and we added a new group in which the X–O_1 and the A–O_1 associations should be equivalently activated at the time of testing because their training was not separated into different phases. That is, this new group (group SO-Random) received intermixed presentations of $X \rightarrow O_1$ and $A \rightarrow O_1$ trials throughout the experi-

TABLE 2
Design Summary of Experiment 2

Group	Treatment: Phase 1	Treatment: Phase 2	Test
SO	$X \rightarrow O_1$, $C \rightarrow O_2$	$A \rightarrow O_1$	X
DO	$X \rightarrow O_1$, $C \rightarrow O_2$	$A \rightarrow$ no O	X
SO-Random	$X \rightarrow O_1$, $C \rightarrow O_2$, $A \rightarrow O_1$		X

Note. A and X were the critical cues. C was included to prevent strong cue generalization. These cues were blue, red, and green colors, counterbalanced. Presentations of X were always followed by Outcome 1 (O_1), whereas presentations of C were always followed by Outcome 2 (O_2). Presentations of A were followed by O_1 in groups SO and SO-Random, whereas they were followed by no outcome in group DO. In groups SO and DO, X was trained before A, whereas in group SO-Random, trial-order was randomized.

ment, so that the relative activation of the X–O_1 and A–O_1 associations at test should be equivalent. If our hypothesis is correct, we should obtain weak responding to X at testing in group SO as compared to groups DO and SO-Random.

Method

Participants and apparatus. Eighty undergraduate students from Deusto University volunteered for the study. Random assignment of participants resulted in 33 participants in group SO, 23 participants in group DO, and 24 participants in group SO-Random. The apparatus was identical to that used in Experiment 1, except that in this experiment (as well as in Experiment 3), the experimental software was run under different computers and a different operating system, which speeded the introduction of refugees into the truck (i.e., the maximum number of refugees that could be introduced in each trial was elevated from 10 refugees per second (in Experiment 1) up to about 30 refugees per second (in Experiments 2 and 3).

Procedure. The procedure was identical to that of Experiment 1, unless otherwise noted. Table 2 summarizes the design of this experiment. During Phase 1, groups SO and DO were exposed to 30 trials in pseudorandom order: 15 trials consisted of cue X, followed immediately by O_1, and 15 consisted of cue C, followed by O_2. During Phase 2, these groups received 15 trials consisting of cue A followed immediately by O_1 (in group SO) or by no O (in group DO). Group SO-Random was exposed to the same 45 trials as group SO, but in this group the trials were not separated into two different phases. Instead, the 45 trials were presented in pseudorandom order as a unique phase. All three groups were then tested on X.

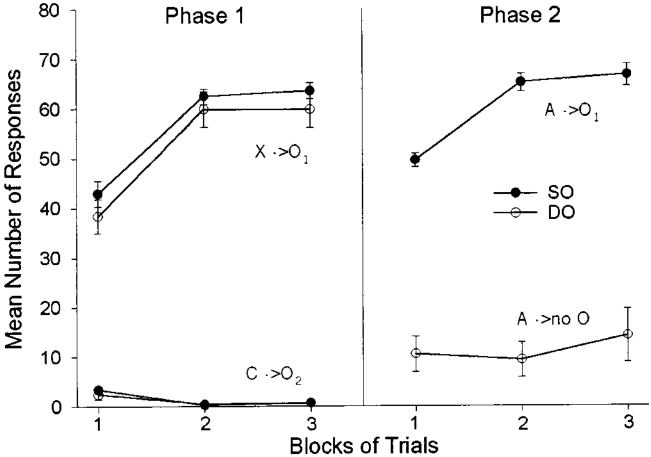
Preanalysis treatment of the data. In this experiment, the same data selection criterion as described in Experiment 1 was used. Following this criterion, the data from one participant from group DO were eliminated from the analyses.

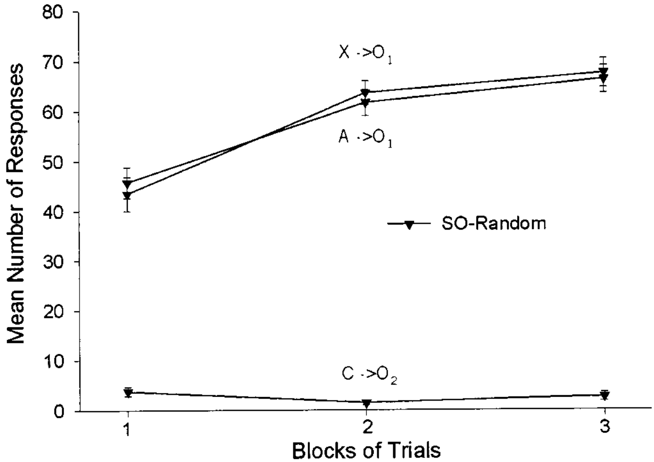
Results and Discussion

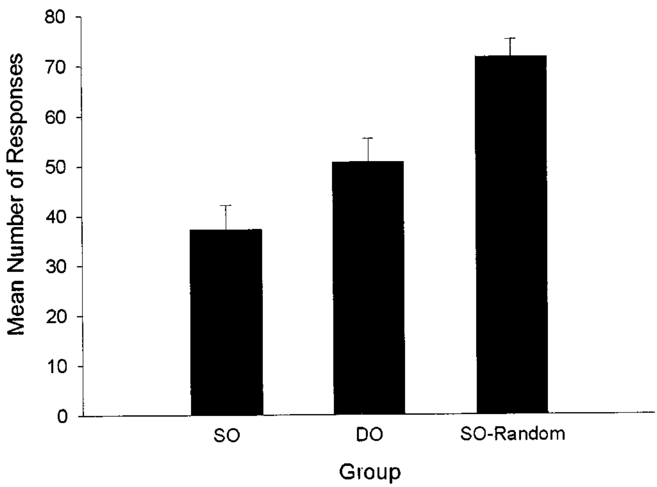
Training. Figure 2 shows the mean number of responses given to X, C, and A during training, in blocks of 5 trials, for group SO-Random (middle panel) and groups SO and DO (top panel). With respect to discrimination between X and C, a 3 (Group: SO vs DO vs SO-Random) × 2 (Cue: X vs C) × 3 (Block of Trials) ANOVA revealed an overall effect of Cue, $F(1, 76) = 1920.57$, $p < .01$, and of Block of Trials, $F(2, 152) = 111.58$, $p < .01$, as well as a Cue × Block of trials interaction, $F(2, 152) = 164.14$, $p < .01$, and no other main effects or interactions. Thus, all groups learned to discriminate between cues X and C.

These panels also show that groups SO and SO-Random did not differ on their responding to A in the last block of trials and that both groups responded more strongly to A than did group DO, which received A → no O instead of A → O trials. A 3 (Group) × 3 (Block of Trials) ANOVA confirmed these impressions by revealing an overall effect of Group, $F(2, 76) = 102.45$, $p < .01$, and of Block of Trials, $F(2, 152) = 61.09$, $p < .01$, as well as a Group × Block of Trials interaction, $F(4, 152) = 11.75$, $p < .01$. Also, pairwise comparisons showed that responding in the third block of trials of A was weaker in group DO as compared to groups SO, $F(1, 76) = 110.70$, $p < .01$, and SO-Random, $F(1, 76) = 99.45$, $p < .01$, which did not differ from each other, $F(1, 76) = .03$, $p > .05$. Thus, all three groups behaved according to the treatment that they received during the training phases.

Testing. The main results of this experiment are presented in the bottom panel of Fig. 2, which shows the mean number of responses to X at test. As can be seen in this figure, group SO showed weaker responding to X at test than group DO, thus replicating the basic effect of interference between elementally trained cues. Most importantly, group SO-Random showed stronger responding to X at test than groups SO and DO. That is, when the $A \rightarrow O_1$ and $X \rightarrow O_1$ training trials are equally recent with respect to testing, interference does not occur. A one-way ANOVA confirmed these impressions by showing an overall Group effect, $F(2, 76) = 15.5$, $p < .01$, and pairwise comparisons showed that responding in group SO was weaker as compared to both group DO, $F(1, 76) = 6.19$, $p < .05$, and group SO-Random, $F(1, 76) = 30.95$, $p < .01$. The difference in responding to X at test between groups SO and SO-Random can be attributed to the order of the presentation of cues. Group SO-Random was exposed to $X \rightarrow O_1$, $A \rightarrow O_1$, and $C \rightarrow O_2$ trials intermixed along the two training stages. In contrast, group SO was exposed to $X \rightarrow O_1$ and $C \rightarrow O_2$ in Phase 1, and to $A \rightarrow O_1$ in Phase 2. This allows the $X–O_1$ and $A–O_1$ associations to be equally


Phase 1
Phase 2
Mean Number of Responses
80
70
60
50
40
30
20
10
0
X ->O1
A ->O1
SO
DO
A ->no O
C ->O2
1
2
3
1
2
3
Blocks of Trials


Mean Number of Responses
80
70
60
50
40
30
20
10
0
X ->O1
A ->O1
SO-Random
C ->O2
1
2
3
Blocks of Trials


Mean Number of Responses
80
70
60
50
40
30
20
10
0
SO
DO
SO-Random
Group

activated at the time of testing in group SO-Random, but not in group SO, in which, because of recency, the A–O_1 association was presumably more strongly activated than the X–O_1 association when the test of X took place.

Interestingly, responding to X at test was also stronger in group SO-Random than in group DO, $F(1, 76) = 7.48$, $p < .01$. There are two potential explanations for this differential responding to X at test between groups DO and SO-Random: (i) The difference in time elapsed between training and testing on X in these two groups might have produced some degree of forgetting in group DO, thus producing some degree of decrement in responding in group DO. (ii) Memory overload might have occurred (i.e., the presentation of any cue and/or outcome after the training of X was completed might overload memory, thus producing forgetting of the previously acquired information). The larger number of trials received in group DO after the last X → O_1 trial in comparison to group SO-Random could be responsible for the weaker responding to X at test in the former group when compared to the latter group. It is possible that any new learning (even if this is the learning of A → no O) could be capable of producing some degree of interference for a previously learned association even when these two associations (X → O and A → no O) do not share any common element. However, as the difference in responding to X at test between groups SO and DO shows, this interference is stronger when the interfering and the target associations share a common element (i.e., in this case, the outcome).

It could be argued that the participants in this experiment could have inferred from the instructions a one-to-one matching rule: They could have thought that there was only one possible outcome for each cue. If this were the case, participants receiving A → O_1 pairings during Phase 2 (group SO) could have inferred that X no longer predicts O_1. Thus, the relatively strong responding shown by participants in group DO could be a consequence of these participants not having seen any trial in which another cue was paired with the same outcome as X. On the other hand, participants in group SO-Random, due to the interspersed presentations of X → O_1 and A → O_1 trials, could have disconfirmed such a rule, thus inferring that X and A were predictors of the same outcome. However, the results of Experiment 1 allow us to disconfirm this view as an explanation of the effect of interference between elementally trained cues. If this one-to-one matching rule were re-

FIG. 2. Experiment 2. Mean number of responses to X, A, and C during training, in blocks of 5 trials (top and center panels), and to X during the test trial (bottom panel). The mean number of responses during training for group SO-Random is depicted in a separated panel (center panel), because in this group training with X, A, and C did not take place in separated phases, as was the case in groups SO and DO (whose mean numbers of responses during training are depicted in the top panel). Error bars represent standard error of means.

sponsible for the interference effect, it would also be evident in groups SO and SO-Interval, and not only in group SO (i.e., a retention interval should have no effect). By contrast, the present results, taken together with those of Experiment 1, add support to the view that interference between elementally trained cues seems to be due to a failure to retrieve the X–O_1 association at the moment of testing, as suggested by Matute and Pineño (1998a). Further evidence against the hypothesis based on the one-to-one matching rule is shown in Experiment 3.

EXPERIMENT 3

In this experiment, like in the preceding experiments, we compared groups that differed in their relative activation of X–O_1 and A–O_1 at testing with a control group in which A was associated to a different outcome during Phase 2 (group DO). Here we used a manipulation which is similar to those that Bouton and his colleagues have sometimes used in order to manipulate the activation of associations in experiments of interference between outcomes (see Bouton, 1993; Brooks & Bouton, 1993; Brooks, Palmatier, Garcia, & Johnson, 1999). The idea is that if a retrieval cue for a certain phase of the study is introduced just before testing, subjects will show during testing behavior which is appropriate to that phase. In this experiment, in group SO-Cue Phase 1 we used one non-reinforced cue (i.e., cue D), which was trained in the same phase in which X was trained (i.e., Phase 1), as a retrieval cue that was presented just before testing and that should be able to reactivate the X–O_1 association in memory. In addition, in group SO-New Cue we introduced just before testing a novel cue which had received no training (i.e., cue F), in order to assess whether training the retrieval cue in the same phase in which X was trained was necessary for retrieval to occur. In experiments of extinction that manipulate the contexts in which the different phases take place, it has been observed that if testing occurs in the context in which acquisition took place or in a whole new context (i.e., different from that in which X was trained and extinguished), a renewal of responding, rather than extinction of responding to X is observed (e.g., Bouton, 1993). Thus, it is possible that in the present experiment, inserting either a retrieval cue from the training phase or a novel cue between the trials in which the interfering association is trained and the test trial could have an effect similar to that of testing an extinguished cue in a novel context. This would also be similar to the effect observed in Experiment 1, in which the insertion of a retention interval served the purpose of separating the test trial from the phase in which the interfering association was trained.

Method

Participants and apparatus. Eighty-eight undergraduate students from Deusto University volunteered for the study. Participants were randomly assigned to four groups (n = 22 participants per group). The apparatus was identical to that used in Experiment 2.

TABLE 3
Design Summary of Experiment 3

Group	Treatment Phase 1	Treatment Phase 2	Treatment Phase 3	Test
SO	X → O_1, C → O_2, D	A → O_1, E	1 E	X
DO	X → O_1, C → O_2, D	A → no O, E	1 E	X
SO-Cue Phase1	X → O_1, C → O_2, D	A → O_1, E	1 D	X
SO-New Cue	X → O_1, C → O_2, D	A → O_1, E	1 F	X

Note. A and X were the critical cues. C was included to prevent strong cue generalization. These cues were blue, red, and green colors, counterbalanced. Presentations of X were always followed by Outcome 1 (O_1), whereas presentations of C were always followed by Outcome 2 (O_2). Presentations of A were followed by O_1 in groups SO, SO-Cue Phase1, and SO-New Cue, whereas they were followed by no outcome in group DO. Cues D, E, and F were used as retrieval cues. These cues were geometric figures (i.e., triangle, circle, and square, counterbalanced) that appeared at a different location from that of the critical cues and were not associated to any outcome, nor were they cues to respond (see text). Only one trial with these cues was presented between Phase 2 and testing.

Procedure. The procedure was identical to that used in Experiments 1 and 2, except that we now used three additional cues (i.e., cues D, E, and F) that could be used as retrieval (or control) cues. These cues were geometrical figures (a circle, a triangle, and a square, counterbalanced) that appeared at the left-bottom corner of the screen rather than on the spy-radio. Thus, these cues were not associated with the possibility of introducing people into the truck, nor were they associated with any outcome. They simply appeared in the screen from time to time. The instructions were identical to those of the previous experiments and did not give any information on the existence of these cues. Moreover, if any response was given during the presentation of these cues, it was treated in the same way as responses that occurred during the ITIs; that is, it had no consequences (it was not reflected in the panel that showed the number of people introduced into the truck or in the score panel, or in any other panel in the screen). The duration of these cues was identical to that of the other cues (i.e., 3 s), and they were subject to the identical ITIs as the other cues.

The design summary is presented in Table 3. In Phase 1, all four groups were exposed to 15 presentations of X, which was always followed by O_1, and 15 presentations of C, which was followed by O_2. In addition, during this phase all groups were exposed to 15 presentations of cue D, intermixed with the presentations of X and C. Then, in Phase 2, groups SO, SO-Cue Phase1, and SO-New Cue were exposed to 15 presentations of A, always followed by O_1, whereas group DO was exposed to 15 presentations of A, always followed by no O. Presentations of A during Phase 2 were intermixed with 15 presentations of cue E in all groups.

The critical difference among groups SO, SO-Cue Phase1, and SO-New Cue was located in Phase 3, that is, just before testing on X. For groups SO and DO, Phase 3 consisted of one presentation of the cue that accompanied the training trials with A during Phase 2 (i.e., cue E). Like in the previous Experiments, group DO served as a control against which the interference expected in group SO was to be assessed. Because there are no breaks between phases, for these two groups, Phase 3 actually consisted of just one more presentation of the cue that was being presented during Phase 2 (i.e., thus cue E was used as a control cue in these groups, since just one additional trials with cue E should be perceived as an additional Phase 2 trial, therefore having no effect).

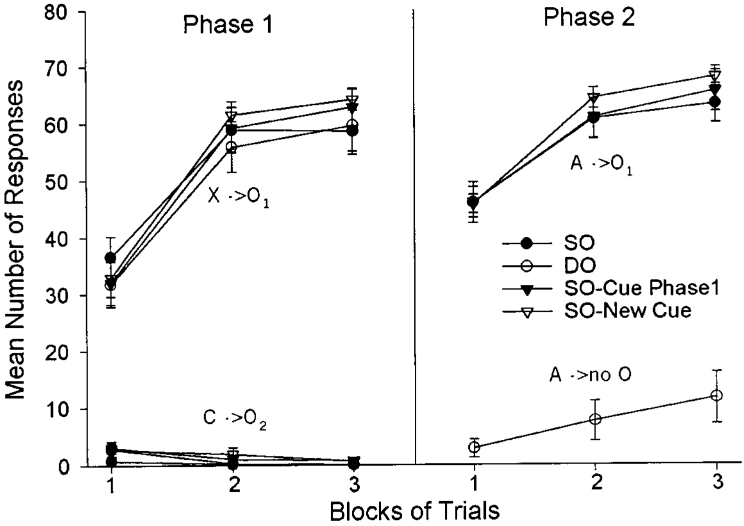
For group SO-Cue Phase1, Phase 3 consisted of one presentation of the cue that accompanied the X $\rightarrow$ O_1 trials during Phase 1 (i.e., cue D). Thus, cue D was used in group SO-Cue Phase1 as a retrieval cue for the X–O_1 association. This should allow this association to be the most strongly activated one at the moment of testing and should, therefore, alleviate the interference effect in this group. For group SO-New Cue, Phase 3 consisted of one presentation of a novel cue that had never been presented during the previous phases (i.e., cue F). Cue F was used in group SO-New Cue as a novel cue that should not retrieve any specific association, but that, like the retention interval used in Experiment 1, should be able to separate the trials of Phase 2 from the test trial, thus preventing the strong activation of the A–O_1 association at the moment of testing (i.e., allowing the X–O_1 and A–O_1 associations to be equally activated at test).

Preanalysis treatment of the data. The data selection criterion was identical to that used in Experiments 1 and 2. Following this criterion, no participant was eliminated from this experiment.

Results and Discussion

Training. The top panel of Fig. 3 shows the mean number of responses given to X, C, and A during training, in blocks of 5 trials. With respect to Phase 1 discrimination training, a 4 (Group: SO vs DO vs SO-Cue Phase1 vs SO-New Cue) $\times$ 2 (Cue: X vs C) $\times$ 3 (Block of Trials) ANOVA revealed an overall effect of Cue, $F(1, 84) = 863.65$, $p < .01$, and of Block of Trials, $F(2, 168) = 207.40$, $p < .01$, as well as a Cue $\times$ Block of Trials interaction, $F(2, 168) = 291.16$, $p < .01$, and no other main effects or interactions. This suggests that all groups learned to discriminate between cues X and C during Phase 1.

This panel also shows that groups SO, SO-Cue Phase1, and SO-New Cue did not differ among each other on their responding to A in the last block of trials of Phase 2, and that these three groups responded more strongly to A than did group DO, which received A $\rightarrow$ no O instead of A $\rightarrow$ O_1 trials during Phase 2. A 4 (Group) $\times$ 3 (Block of Trials) ANOVA confirmed these impressions, by revealing an overall effect of Group, $F(3, 84) = 82.99$, $p <$ .01, and of Block of Trials, $F(2, 168) = 118.10$, $p < .01$, as well as a Group $\times$ Block of Trials interaction, $F(6, 168) = 4.31$, $p < .01$. Pairwise



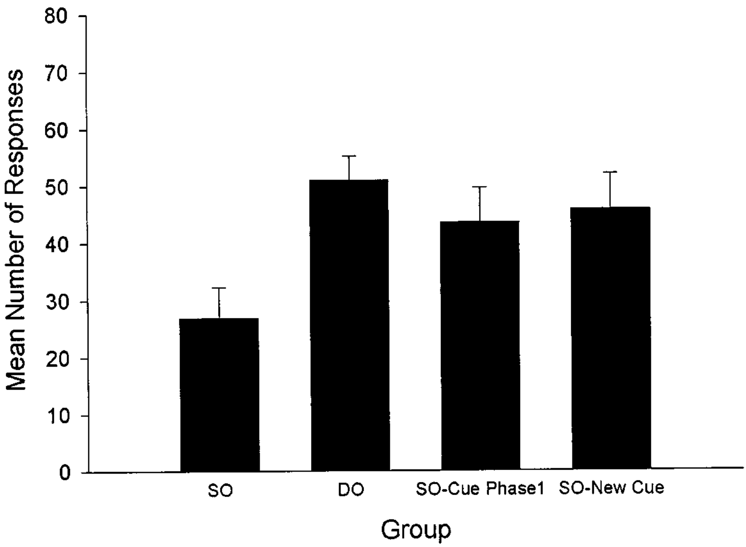


FIG. 3. Experiment 3. Mean number of responses to X, A, and C during training, in blocks of 5 trials (top panel), and to X during the test trial (bottom panel). Error bars represent standard error of means.

comparisons showed that responding in the third block of trials of A was weaker in group DO as compared to groups SO, $F(1, 84) = 112.83$, $p < .01$, SO-Cue Phase1, $F(1, 84) = 122.66$, $p < .01$, and SO-New Cue, $F(1, 84) = 134.46$, $p < .01$, which did not differ among each other (all *p*s $> .1$). Thus, all four groups behaved according to the treatment that they received during the training phases.

Testing. The main results of this experiment are presented in the bottom panel of Fig. 3, which shows the mean number of responses to X at test. As can be seen in this figure, Group SO showed weak responding to X at test as compared to group DO. This replicated the effect of interference between elementally trained cues. Most importantly, group SO also showed weak responding as compared to groups SO-Cue Phase1 and SO-New Cue. A one-way ANOVA on the test of X confirmed these impressions by showing an overall Group effect, $F(3, 84) = 3.48$, $p < .05$, and pairwise comparisons showed that responding in group SO was weaker as compared to group DO, $F(1, 84) = 9.28$, $p < .01$, group SO-Cue Phase1, $F(1, 84) = 4.42$, $p < .05$, and group SO-New Cue, $F(1, 84) = 5.77$, $p < .05$. Groups DO, SO-Cue Phase1, and SO-New Cue did not differ among each other (all *p*s $> .1$).

The stronger responding shown in groups SO-Cue Phase1 and SO-New Cue as compared to group SO suggests that the cue presented just before testing in groups SO-Cue Phase1 and SO-New Cue prevented the A–O_1 from being strongly activated at testing, thereby allowing X to control behavior. Although the role of cue D was supposed to be more specific and, in consequence, perhaps stronger than that of cue F, the results show that the effect of this cue was similar to that of a novel cue. That is, like the retention interval used in Experiment 1, a retrieval cue for Phase 1 (i.e., cue D) or a novel cue (i.e., cue F) presented just before testing was equally able to separate the test trial from the interfering trials and therefore alleviate the interference effect, presumably not by directly activating the X–O_1 association but by preventing the A–O_1 association to interfere with the retrieval of the X–O_1 association at test.

The results for group SO-Cue Phase1 are similar to results reported by Bouton and his colleagues in paradigms of interference between outcomes, where they have shown that a retrieval cue for a certain phase of the study can produce responding appropriate for that phase (e.g., Brooks & Bouton, 1993; Brooks *et al.*, 1999). However, the results for group SO-New Cue in the present experiment also show that it is not necessary for the retrieval cue to be specific to the phase in which X was trained. The only requirement seems to be to separate the test trial from the interfering trials, be it through the introduction of a retrieval or a novel cue or, as shown in Experiment 1, through the use of a retention interval. In either case, it seems clear that the interfering association does not interfere with the target association unless testing takes place in a context in which the interfering association predominates over the target one.

Interestingly, similar results have also been found in experiments about interference between outcomes in which novel contexts (or retention intervals), instead of retrieval cues, were used in order to retrieve associations (see, e.g., Bouton, 1991, 1993; Bouton & Bolles, 1979; Bouton & King, 1983; Bouton & Peck, 1989; Rosas & Bouton, 1997a, 1997b). Thus, the present results show a recovery effect of the interference between elementally trained cues, which occurs analogously to recovery in experiments of interference between outcomes, such as extinction and counterconditioning (e.g., Bouton, 1993; Brooks & Bouton, 1993; Brooks *et al.*, 1999).

GENERAL DISCUSSION

Matute and Pineño (1998a) had shown that the acquisition of a second cue–outcome association during a second stage of an experiment could interfere with the retrieval of a previously acquired association between a different cue and the same outcome. They assessed this effect against various controls, which taken together suggested that the effect only occurred when the interfering association was more strongly activated than the target one at testing. In order to further explore the conditions that yield interference between elementally trained cues, in the present experiments, we performed new manipulations that had not been used by Matute and Pineño. The results add support to the view that the relative activation of the two associations at testing is a critical factor in producing this effect. Experiment 1 showed that giving the A $\rightarrow$ O trials just before the test on X was important in order to obtain the effect. Experiment 2 extended those results by showing that the effect occurred only when X and A were trained in separate phases, thus allowing the A–O association to be more strongly activated than the X–O association at the time of testing. When X and A were trained in a unique phase, responding to X at test was not impaired, presumably because the X–O and A–O associations were equally activated when the test trial was presented. Finally, Experiment 3 showed that the presentation before testing of a retrieval cue for the association which was acquired during Phase 1 (i.e., the X–O association) or the presentation of a novel retrieval cue reactivated responding to X. Presumably, the presentation of a cue just before testing served the purpose of separating the test trial from the Phase 2 A $\rightarrow$ O trials, quite possibly in a way similar to that provided by the introduction of a retention interval (Experiment 1). The effect of separating Phase 2 and testing (either through a retention interval or through the introduction of a cue) seems to be that the A–O association is no longer strongly activated in memory when the test trial is presented, thereby allowing X to control behavior. Taken together, these results support our hypothesis that the relative activation of the association at testing modulates interference between elementally trained cues. Moreover, in the present experiments we used a preparation and a dependent variable that were different from those used by Matute and Pineño (1998a), and the basic interference effect of group SO was replicated in all three experiments, which shows that this effect is not specific to the use of a particular preparation or dependent variable.

As Matute and Pineño (1998b) noted, there is a notable parallelism between these experiments and those on retroactive interference between outcomes (i.e., experiments on extinction and counterconditioning, in which a single cue is paired to two different outcomes in different phases; see e.g., Bouton, 1993, Rescorla, 1996a). Our effect of interference between elementally trained cues can be regarded as a related type of retroactive interference, except that in this case two cues are paired to the same outcome in different phases, rather than vice versa. Moreover, our effect, like interference between outcomes, seems to be due to a failure to retrieve the target association during testing. More specifically, in our experiments interference probably occurs because the X–O association can not be retrieved, due to the strong activation of the A–O association at testing. Similarly, in experiments on interference between outcomes, such as extinction, interference presumably occurs because the alternative association (e.g., X–no O) is more strongly activated at testing than the target one (X–O). If a retention interval is introduced between the extinction phase and testing, spontaneous recovery of the response is observed (Pavlov, 1927), presumably because the interfering association is no longer active in memory (Bouton, 1993). Experiment 1 showed a similar effect for a retention interval on interference between elementally trained cues. Moreover, in experiments on interference between outcomes, if a retrieval cue for extinction is presented before testing, spontaneous recovery is attenuated (Brooks & Bouton, 1993; Brooks *et al.*, 1999), and if testing occurs in a context different from that in which the interfering phase (i.e., extinction) occurred, interference is not observed (e.g., Bouton, 1993). Experiment 3 showed a similar effect on interference between cues: separating the test trial from those trials in which the interfering association was trained, either by inserting a novel cue or by inserting a cue from the phase in which X was trained, prevented interference from occurring. Finally, if acquisition and extinction trials are randomly intermixed rather than presented in different phases, extinction is not observed (e.g., Hartman & Grant, 1960). This result is analogous to the absence of cue interference observed in group SO-Random in Experiment 2. In all these cases, the interfering association is no longer more strongly activated in memory than the target one at testing.

Interestingly, these similarities could allow us to integrate the literature on interference between cues (e.g., blocking, relative validity) and on interference between outcomes (e.g., extinction, counterconditioning), which are generally presented as independent fields of study. Traditional associative models which explain cue interference, such as Rescorla and Wagner's (1972), fail to explain interference between outcomes (see e.g., Bouton, 1993; Rescorla, 1996a, 1996b), nor can they explain the results that we have presented here and elsewhere on interference between elementally trained cues (Matute & Pineño, 1998a, 1998b). On the other hand, theories that explain interference between outcomes (e.g., Bouton, 1993) do not attempt to explain interference between cues but could, in principle, be extended to explain both our results and other cases of cue interference.

Matute and Pineño (1998b) speculated about several ways in which several theories could be extended to account for this effect. One possibility, which seems quite compatible with the present results, had to do with an extension of theories that have been developed to account for interference between outcomes (e.g., Bouton, 1993). For example, according to Bouton, during an extinction experiment, the cue signals two different outcomes at different phases (i.e., X–O in Phase 1 and X–no O in Phase 2), and thus, interference (i.e., extinction) is shown when the interfering (X–no O) association predominates over the target association (X–O) at testing. This view could be extended to account for the present results if we assume that the participants first learn that the outcome is signalled by X, and then they learn that the outcome is signalled by A. If the test trial is presented while the participant is expecting A to be presented as a signal for when the outcome will occur, the presentation of X cannot immediately activate the outcome representation. In this framework, the behavior observed during testing will depend on which of those associations is retrieved at testing. For example, in Experiment 1, interference was observed only when the test of X took place immediately after completion of the interfering training phase (i.e., A $\rightarrow$ O training). The introduction of a retention interval before testing in the other group probably allowed the two associations to be similarly activated at testing, thus allowing X, the cue that was present, to elicit a response. Thus, this can explain why the introduction of retention intervals before testing in Experiment 1, the introduction of a retrieval cue in Experiment 3 (or contextual manipulations, see Matute & Pineño, 1998a), and the random order for training of X and A used in Experiment 2 yielded good responding to X (e.g., spontaneous recovery and renewal effects; see Bouton). Presumably, all of these manipulations result in the interfering association not being more strongly activated than the target one at the time (or context) in which testing takes place.

It could be argued that interference between outcomes occurs in situations in which there are conflicting associations (i.e., X–O then X–no O), whereas in the present case the two associations are compatible (i.e., X–O then A–O). Thus, although it seems clear that A interferes with X for activation of the outcome representation, it still needs to be explained why the strong activation of the A–O association during the test phase does not produce a response. One possibility could be to assume that an inhibitory association between X and A is acquired during training (because when A is present, X is absent, see Espinet, Iraola, Bennett, & Mackintosh, 1995), and this inhibitory association then prevents responding to the representation of the absent cue, A, which is activated at testing when X is presented (Bennett, Scahill, Griffiths, & Mackintosh, 1999; Mackintosh & Bennett, 1997). Although this explanation was suggested to account for a rather different phenomenon, Matute and Pineño (1998b) suggested that it could plausibly be extended to explain why the strong activation of A did not produce responding at test in the experiments of interference between elementally trained cues. However, the results of the present experiments allow us to discard this explanation. According to Espinet *et al.* and Bennett *et al.*, the formation of inhibitory associations between X and A should be favored when the X and A trials are intermixed in the same phase of the study. This is exactly the condition used in group SO-Random in Experiment 2, which, if this view were correct, is the group that would have shown the interference effect. However, it is not group SO-Random but group SO that has consistently shown the interference effect in the present experiments as well as in previous research. Moreover, as mentioned in the Introduction, the contextual (Matute & Pineño, 1998a) and one-trial effects (Ortega & Matute, in press) also suggest that inhibitory associations are not responsible for the effect of interference between elementally trained cues.

Another possibility is to assume that if the test context is strongly activating the A–O association (i.e., context–A–O or context–(A–O)), the occurrence of X when A, rather than X, is expected to occur in the test context might be processed as ‘‘no A.’’ If this were the case, a conflicting association (context–no A) similar to those that interfere in extinction experiments (i.e., X–no O) might be activated, thus interfering with the occurrence of the response. Another possibility is that the outcome representation has a limited activation potential, and thus, a given cue will have difficulties in activating the outcome representation if another cue is already strongly activating it at that particular moment. The data available so far suggest that these are, at least, plausible explanations that are in agreement with the present finding that the relative activation of the two (excitatory) associations at testing modulates the interference effect.

In sum, although more empirical and theoretical effort will be necessary in order to provide a complete explanation of the effect of interference between elementally trained cues, the present experiments add support to the hypothesis proposed by Matute and Pineño (1998a, 1998b) on the importance of the relative activation of the associations at testing. Although tentative and not formalized yet, this hypothesis also suggests that extending theories of interference between outcomes (e.g., Bouton, 1993) to account for interference between cues is probably the most plausible and integrative way to account for most of the data available up to now.

REFERENCES

Arcediano, F., Ortega, N., & Matute, H. (1996). A behavioural preparation for the study of human Pavlovian conditioning. *Quarterly Journal of Experimental Psychology,* **49B,** 270–283.

Bennett, C. H., Scahill, V. L., Griffiths, D. P., & Mackintosh, N. J. (1999). The role of inhibitory associations in perceptual learning. *Animal Learning & Behavior,* **27,** 333–345.

Bouton, M. E. (1991). Context and retrieval in extinction and in other examples of interference in simple associative learning. In L. W. Dachowski and C. F. Flaherty (Eds.), *Current topics in animal learning: Brain, emotion, and cognition* (pp. 25–53). Hillsdale, NJ: Erlbaum.

Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin,* **114,** 80–99.

Bouton, M. E., & Bolles, R. C. (1979). Contextual control of the extinction of conditioned fear. *Learning and Motivation,* **10,** 445–466.

Bouton, M. E., & King, D. A. (1983). Contextual control of the extinction of conditioned fear: Tests for associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes,* **9,** 248–265.

Bouton, M. E., & Peck, C. A. (1989). Context effects on conditioning, extinction, and reinstatement in an appetitive conditioning situation. *Animal Learning & Behavior,* **17,** 188–198.

Brooks, D. C., & Bouton, M. E. (1993). A retrieval cue for extinction attenuates spontaneous recovery. *Journal of Experimental Psychology: Animal Behavior Processes,* **19,** 77–89.

Brooks, D. C., Palmatier, M. I., Garcia, E. O., & Johnson, J. L. (1999). An extinction cue reduces spontaneous recovery of a conditioned taste aversion. *Animal Learning & Behavior,* **27,** 77–88.

Chandler, C. C. (1993). Accessing related events increases retroactive interference in a matching recognition test. *Journal of Experimental Psychology: Learning, Memory & Cognition,* **19,** 967–974.

Dickinson, A., & Burke, J. (1996). Within-compound associations mediate the retrospective revaluation of causality judgements. *Quarterly Journal of Experimental Psychology,* **49B,** 60–80.

Espinet, A., Iraola, J. A., Bennett, C. H., & Mackintosh, N. J. (1995). Inhibitory associations between neutral stimuli in flavor-aversion conditioning. *Animal Learning & Behavior,* **23,** 361–368.

Hartman, T. F., & Grant, D. A. (1960). Effect of intermittent reinforcement on acquisition, extinction, and spontaneous recovery of the conditioned eyelid response. *Journal of Experimental Psychology,* **60,** 89–96.

Kamin, L. J. (1968). ''Attention-like'' processes in classical conditioning. In M. R. Jones (Ed.), *Miami symposium on the prediction of behavior: Aversive stimulation* (pp. 9–31). Miami: Univ. of Miami Press.

Mackintosh, N. J. (1975). A theory of attention: Variations in the associability of stimuli with reinforcement. *Psychological Review,* **82,** 276–298.

Mackintosh, N. J., & Bennett, C. H. (1997). Inhibitory associations in taste aversion conditioning. In *IX Congreso de la Sociedad Española de Psicología Comparada.* Salamanca: Spain.

Matute, H., & Pineño, O. (1998a). Stimulus competition in the absence of compound conditioning. *Animal Learning & Behavior,* **26,** 3–14.

Matute, H., & Pineño, O. (1998b). Cue competition in the absence of compound training: Its relation to paradigms of competition between outcomes. In D. L. Medin (Ed.), *The psychology of learning and motivation, Vol. 38* (pp. 45–81). San Diego: Academic Press.

Miller, R. R., & Matzel, L. D. (1988). The comparator hypothesis: A response rule for the expression of associations. In G. H. Bower (Ed.), *The psychology of learning and motivation, Vol. 22* (pp. 51–92). San Diego: Academic Press.

Ortega, N., & Matute, H. (in press). *Interference between elementally trained stimuli can take place in one trial. Learning and Motivation.*

Pavlov, I. P. (1927). *Conditioned reflexes.* London: Clarendon.

Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review,* **87,** 532–552.

Rescorla, R. A. (1996a). Preservation of Pavlovian associations through extinction. *Quarterly Journal of Experimental Psychology,* **49B,** 245–258.

Rescorla, R. A. (1996b). Spontaneous recovery after training with multiple outcomes. *Animal Learning & Behavior,* **24,** 11–18.

Rescorla, R. A. (1997). Spontaneous recovery after Pavlovian conditioning with multiple outcomes. *Animal Learning & Behavior,* **25,** 99–107.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory* (pp. 64–99). New York: Appleton.

Rosas, J. M., & Bouton, M. E. (1997a). Additivity of the effects of retention interval and context change on latent inhibition: Toward resolution of the context forgetting paradox. *Journal of Experimental Psychology: Animal Behavior Processes,* **23,** 283–294.

Rosas, J. M., & Bouton, M. E. (1997b). Renewal of a conditioned taste aversion upon return to the conditioning context after extinction in another one. *Learning and Motivation,* **28,** 216–229.

Shanks, D. R. (1985). Forward and backward blocking in human contingency judgment. *Quarterly Journal of Experimental Psychology,* **37B,** 1–21.

Van Hamme, L. J., & Wasserman, E. A. (1994). Cue competition in causality judgments: The role of nonpresentation of compound stimulus elements. *Learning and Motivation,* **25,** 127–151.

Wagner, A. R. (1981). SOP: A model of automatic memory processing in animal behavior. In N. E. Spear & R. R. Miller (Eds.), *Information processing in animals: Memory mechanisms* (pp. 5–47). Hillsdale, NJ: Erlbaum.

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