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Proactive Interference in Human Predictive Learning

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The impairment in responding to a secondly trained association because of the prior training of another (i.e., proactive interference) is a well-established effect in human and animal research, and it has been demonstrated in many paradigms. However, learning theories have been concerned with proactive interference only when the competing stimuli have been presented in compound at some moment of the training phase. In this experiment we investigated the possibility of proactive interference between elementally-trained stimuli at the acquisition and at the retrieval stages in a behavioral task with humans. After training a cue-outcome association we observed retardation in the acquisition of an association between another cue and the same outcome. Moreover, after asymptotic acquisition of the secondly trained association, impairment of retrieval of this secondly trained association was also observed. This finding of proactive interference between elementally-trained cues suggests that interference in predictive learning and other traditional interference effects could be integrated into a common framework.

Interference among cues is a central topic in associative learning research. Cue interference is well represented by Kamin's early studies (e.g., 1968) with rats, where he found that the training of two cues in compound after the isolated training of one of them produced weak responding to the other one. That is, if a target cue, B, is trained with another cue, A, as a predictor of an outcome (O) after cue A has been trained as a predictor of that outcome, weak responding to B will be observed at testing. This is the well known blocking effect. Other cue interference effects in the animal learning literature are overshadowing (Pavlov, 1927) and relative validity (Wagner, Logan, Haberlandt, & Price, 1968). These effects have been found with humans as well (e.g., Dickinson, Shanks, & Evenden, 1984; Matute, Arcediano, & Miller, 1996; Price & Yates, 1993; Van Hamme, Kao, & Wasserman, 1993).

According to associative theories of learning, the acquisition of a cue-outcome association interferes with the acquisition (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972) or the expression (e.g., Miller & Matzel, 1988) of another cue-outcome association only when both cues have been presented in compound at some point during acquisition (e.g., the blocking effect); if cues are separately paired with the outcome, none of them will be able to predict the outcome when the other one is presented, so there should be no interference. However, recent research with rats (Escobar, Arcediano, & Miller, 2001; Escobar,

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Matute, & Miller, 2001) and humans (e.g., Matute & Pineño, 1998a, 1998b; Ortega & Matute, 2000; Pineño, Ortega, & Matute, 2000) has shown that interference effects can occur between elementally-trained cues, that is, between cues that have never received compound training. The original finding comes from Matute and Pineño's (1998b) studies of predictive learning with humans. They reported that giving B-O pairings (i.e., a colored light presented with a positive outcome) in Phase 2 after A-O pairings (i.e., another colored light presented with the same outcome) in Phase 1 resulted in weak responding to the target cue, A, at test (i.e., retroactive interference). They found that this effect was not due to the time elapsed between Phase 1 and testing, to memory overload, or to blocking by context. Moreover, this effect occurs when the cues that interfere with each other share the same outcome; that is, there is no interference when the interfering cue, B, is paired with a different outcome during Phase 2 (Pineño & Matute, 2000; Escobar, Arcediano, & Miller, 2001).

Although the finding of cue interference between elementally-trained cues is problematic for contemporary learning theories, it is consistent with results in the human verbal learning literature. Interference processes have been largely studied in the paired associate tradition (e.g., see Postman & Underwood, 1973), in which participants learned the association between a cue item and a response item, in paradigms such as A-B, A-C or A-B, C-B. More specifically, the reported effect of interference between elementally-trained cues in predictive learning (e.g., Matute & Pineño, 1998b), can be seen as an analogue to the retroactive interference effect observed in the A-B, C-B verbal interference paradigm. In this paradigm, retroactive interference is said to occur when the learning of C-B after the previous learning of A-B impairs the subsequent recall of the A-B association (Cheung & Goulet, 1968; Keppel, Bonge, Strand, & Parker, 1971; Schwartz, 1968).

Moreover, several different manipulations have been shown to have similar effects in cue interference between elementally-trained cues in predictive learning and in other retroactive interference paradigms. For example, in Matute and Pineño's (1998b) predictive learning experiments, interference was attenuated when the interfering and target associations were trained in different contexts and testing occurred in the context in which the target association had been trained. This is a well demonstrated effect in several other different paradigms: In verbal learning (Bidoleau & Schlosberg, 1951), in serial learning (Kanak & Stevens, 1992), and in several studies of long-term retention in rats (Chiszar & Spear, 1969; Spear, 1971; Zentall, 1970). In all of these studies it has been shown that memories established in a context similar to that of testing are more likely to be retrieved than memories established in a context different from that of testing. Additionally, manipulations on the temporal point in which the interpolated learning takes place have also shown similar results in the interference between elementally-trained cues in predictive learning as well as in the paired associate tradition. Postman (1971) reported some experiments in which the first list recall was higher when a retention interval was introduced just before the test phase, in comparison to the introduction of a retention interval between the original and the interpolated learning phases. Moreover, Postman, Stark, and Fraser (1968) showed that when recall of both the firstly and secondly learned lists was required, the responses from the secondly learned list were likely to be given first on an immediate test; however, after a retention interval, the responses from the first list were likely to be given first. Similarly, Pineño et al. (2000) showed that the introduction of a retention interval between Phase 2 and testing reduced retroactive interference in predictive learning, but this did not occur when the retention interval was introduced between Phases 1 and 2 of training. Seemingly, manipulations that generate a separation between Phase 2 and testing are able to reduce the activation of the most recently trained association, therefore allowing the retrieval of the other association.

In sum, this all suggests that interference occurs when the two associations share a common element and the interfering association is more strongly activated than the target association at the time of testing (e.g., because of recency or contextual manipulations). Apparently, if the interfering cue is strongly predicting the outcome when the target cue is presented at testing, retrieval of the outcome representation by the target cue is impaired (see Matute & Pineño, 1998a; Pineño et al., 2000, for further discussion).

A tentative explanation of these effects can be constructed as an extension of Bouton's (e.g., 1997) retrieval theory. According to this approach, when two conflicting associations are trained to asymptote (e.g., when one cue has been paired with two different outcomes or, extending this theory, when one outcome has been paired with two different cues), the memory of the second association in which an event is involved is the most likely to manifest if testing occurs immediately after training and in the same context. However, when the memory of the second association is not activated (e.g., because testing takes place in a novel context or after a period of time), then the firstly trained association is the most likely to manifest at test. Consequently, the attenuation of the interference effects would occur not by means of directly activating the target association, but by preventing the interfering association from being strongly activated during testing.

Following this explanation, each of the two associations (regardless of the order in which they have been trained) should be able to interfere with the other one as a function of which one is more strongly activated at the time of testing (be it because of recency or because of other manipulations such as, for example, the use of contextual or discrete retrieval cues). In this vein, elementally trained associations should be able to interfere with each other not only retroactively but also proactively. Indeed, a recent study of retroactive interference with rats by Escobar, Matute, and Miller (2001), provides some evidence of proactive interference. Escobar et al. tested not only for responding to the firstly trained cue, B, but also for responding to the secondly trained cue, A. They observed that when the secondly trained association was tested in the context in which the firstly trained association had been trained, weak responding to the secondly trained cue was obtained. This is suggestive of a proactive interference effect. Unfortunately, their primary concern was retroactive interference, and therefore they did not include control conditions for proactive interference. Another example of proactive interference could be the latent inhibition effect, in which the exposure to a stimulus alone during Phase 1 retards the conditioning to that stimulus during Phase 2. According to Bouton (1993), the first learning experience (cue-nothing) prevails over the second one (cue-outcome).

In the present experiment we aimed to further assess the prediction that it is the relative activation of the associations at testing which produces interference, by testing for whether elementally trained cues are also sensitive to proactive interference. With the exception of the preliminary results with rats observed by

Escobar, Matute, and Miller (2001), and the latent inhibition effect in interference between outcomes, we are not aware of this effect being previously reported in the predictive learning literature, although proactive interference in other paradigms with humans (e.g., Bennett, 1975; Brosgole, 1976) as well as with animals (e.g., Grant, 1975) is a quite well established effect (but see Crowder, 1967; Kehoe, 1963). This is important in that, if proactive interference between elementally trained cues were observed to occur in predictive learning, it would add to the growing body of literature that suggests that interference between cues (e.g., Matute & Pineño, 1998a) and between outcomes (e.g., Bouton, 1993) in predictive learning can probably be integrated into a common framework along with interference effects from other areas.

Overview of the Experiment

We studied proactive interference, trying to answer the following questions: (1) If a cue is paired to an outcome after a different cue has been trained as a predictor of the same outcome, will the acquisition of the second cue-outcome association be retarded?, and (2) once the second cue-outcome association is acquired, could proactive interference still be observed during subsequent retrieval?

During acquisition we assessed how the B-O_1 association was acquired during Phase 2. For three of four groups, Cue A was trained as a predictor of O_1 during Phase 1 (Groups SO, Same Outcome). For the other group, Cue A predicted a different outcome, O_2, during Phase 1 (Group DO, Different Outcome). Thus, we assessed whether the acquisition of an association with one outcome during Phase 1 in the SO groups impaired their acquisition of the association of B with the same outcome during Phase 2, as compared to the acquisition in Group DO, that received the identical exposure to the task but did not acquire an association to O_1 during Phase 1. Thus, Groups SO are analogous to the A-B,C-B condition in the paired associate literature, and the control group, Group DO, is analogous to the A-B, C-D control condition commonly used in the paired associate paradigm.

In addition, we also assessed proactive interference once the target association had been acquired. Certainly, it would make no much sense to perform a direct test of retrieval immediately after all groups have acquired the target association because all of them would respond appropriately at that time. However, if our hypothesis is correct, anything that is able to separate Phase 2 from testing (e.g., a retention interval, a contextual change, or even a discrete cue presented between training and testing) should be able to reduce the activation of the most recently trained association, consequently allowing the other association to interfere with it. This idea receives support from studies of retroactive interference (e. g., Pineño et al., 2000) and can be tested in this experiment by means of a manipulation that has sometimes been used to vary the activation of associations in animal experiments concerning interference between outcomes (e.g., Brooks & Bouton, 1993). The idea is that if a discrete stimulus present during a certain phase of the study is presented just before testing, during testing subjects will show behavior that is appropriate to that phase. This manipulation has also been used within the retroactive interference paradigm with elementally-trained cues (e.g., Escobar, Matute, & Miller, 2001, with rats; Pineño et al., 2000, with humans).

Method

Subjects

One hundred and six undergraduate students from Deusto University volunteered for the study. Random assignment of participants resulted in 30 participants in Group SO, 26 participants in Group DO, 24 participants in Group SO-Cue2, and 26 participants in Group SO-Novel Cue.

Apparatus

The experiment was run in a large room with personal computers, with the participants responding through the keyboard. Two sets of fifty and fifty-six participants were run in two different days. In both days, subjects were randomly distributed across the four experimental groups. Participants had about 1.5 m of distance between each other, each participant being exposed to a different experimental condition (and counterbalancing of stimuli) than the two adjacent participants.

Procedure

The design summary is presented in Table 1. In Phase 1, Groups SO, SO-Cue2 and SO-Novel Cue were exposed to 15 presentations of A, which was always followed by O_1, whereas Group DO was exposed to 15 presentations of A always followed by O_2. In addition, during Phase 1 all groups were exposed to 15 presentations of a retrieval cue, D, intermixed with the presentations of A. Then, in Phase 2, all groups were exposed to 15 presentations of B, always followed by O_1, interspersed with fifteen presentations of cue C, which was always followed by O_3 (i.e., C-O_3). Presentations of C-O_3 trials were included in order to prevent cue generalization that would result in strong responding appropriate to O_1 to all cues. Presentations of B and C during Phase 2 were intermixed with 15 presentations of a retrieval cue, E, in all groups.

Table 1
Design of the Experiment.

Group	Treatment			Test
	Phase 1	Phase 2	Phase 3	
SO	$A \rightarrow O_1$, D	$B \rightarrow O_1$, $C \rightarrow O_3$, E	D	B
DO	$A \rightarrow O_2$, D	$B \rightarrow O_1$, $C \rightarrow O_3$, E	D	B
SO-Cue2	$A \rightarrow O_1$, D	$B \rightarrow O_1$, $C \rightarrow O_3$, E	E	B
SO-Novel Cue	$A \rightarrow O_1$, D	$B \rightarrow O_1$, $C \rightarrow O_3$, E	F	B

Note. A and B were the critical cues. C was included to prevent strong cue generalization. Cues A, B, and C were blue, red, and green colors, counterbalanced. Presentations of A were followed by O_1 in groups SO, SO-Cue2, and SO-Novel Cue, whereas they were followed by O_2 in group DO. Presentations of B during training were always followed by O_1 whereas presentations of C were always followed by O_3. O_1 was a positive outcome, O_2 was a neutral outcome and O_3 was a negative outcome. 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 a cue to respond (see text).

The other critical difference between groups was located in Phase 3, that is, just before testing. For Groups SO and DO, Phase 3 consisted of one presentation of cue D, that is, the retrieval cue that occurred during Phase 1 along with the training of A-O_1 (Group SO) or A-O_2 (Group DO). This retrieval cue should be able to prevent the strong activation of the B-O_1 association that would otherwise be expected at the time of testing, because of recency. This weak activation of B at test should in turn favor the interference effect in Group SO (in which A-O_1, an interfering association because it shared the outcome with the target association, B-O_1, could be reactivated) as compared to Group DO (in which none potentially interfering association had been trained). Moreover, if, according to our hypothesis, any disruption between Phase 2 and testing could be enough to diminish the strong activation of the B-O_1 association, interference should occur also in Group SO-Novel Cue (for which Phase 3 consisted of one presentation of a novel cue), as compared to Group DO (for which no interfering association had been trained). Finally, for Group SO-Cue2, Phase 3 consisted of one additional presentation of the cue included in Phase 2 (i.e., cue E). Because there was no break between phases, for this group Phase 3 actually consisted of just one more presentation of the cue that was being presented during Phase 2; thus cue E was used as a control, because just one additional presentation of cue E should be perceived as an additional Phase 2 trial, therefore producing no effect. Trial order for each phase was pseudorandom, with no more than two trials of the same type occurring in succession. After Phase 3, all groups were exposed to one test trial with B, which was presented after the same intertrial interval (ITI) used in the previous phases.

The experimental preparation that we used was the *Spy-Radio* task, a behavioral task for use with humans previously used in Pineño et al. (2000) and Pineño & Matute (2000) (A demonstration version of this program can be downloaded from http://sirio.deusto.es/matute/software.html). The participant's task was to rescue a group of refugees by helping them to escape from a war zone in several trucks. A translation from Spanish of the instructions that the participants received 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 to 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.

The fourth instruction screen informed participants that they would possibly rescue refugees in different towns; these towns would provide different contexts that could be manipulated by the experimenter. Although contextual changes were not used in the present experiment, we maintained the four instructional screens of this program in order to avoid making more changes than necessary between different series of experiments using this same preparation. 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 traveling. 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.

The top of the screen showed a "spy-radio" that consisted of a panel in which six colored lights could be presented. Cues A, B, and C were blue, red, and green lights in the spy radio, counterbalanced. In this experiment, each time that a cue was presented, all six panels were illuminated with the color of that cue. Cue duration was 3 s. During the ITIs, the lights were turned off (i.e., gray). The ITI duration was random with a range between 3 and 7 s, and a mean of 5 s. While the lights were on, each response (i.e., pressing the space bar once) placed one refugee in the truck. If the participant maintained the space bar pressed down while the lights were on, up to 30 refugees per second could be placed in the truck with the computers used in this experiment. On each trial, the termination of the cue was immediately followed by 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 "Road closed" and, (b) maintaining previous score. Outcome 3 (O_3) consisted of (a) the message "[N] refugees have been killed!!!" and, (b) losing one point for each refugee who died in the truck. Outcome messages were presented for 3 s. Outcomes were not counterbalanced because our dependent variable was the mean number of responses given during the presentation of B. Thus, B had to be always paired to an appetitive outcome. Otherwise, strong or weak responding at test would depend on outcome counterbalancing rather than on whether interference exists or not.

The number of refugees that participants risked taking in each truck was our dependent variable. Presumably, the more certain they were that the trip would be successful (i. e., O_1), the greater number of refugees they would take, whereas the more certain they were that the truck would explode (i.e., O_3), the smaller number of refugees they would take. Additionally, because introducing refugees did not have any effect on the score when O_2 followed the cue, we expected the participants to take no refugees when the cue was followed by O_2.

One score panel on the screen provided information during the experiment. The panel showed the number of people that the participant was introducing in the truck on each trial. Although bar presses that occurred while the outcome message was present had no consequences, the score 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 set to zero. Responses that occurred during the ITIs had no consequences and were not reflected in the panel. Thus, only responses that occurred while a cue was presented resulted in refugees traveling in the truck and participants gaining or losing points (if O_1 or O_3 followed the cue) or keeping the previous score (if O_2 followed the cue).

The retrieval cues (i.e., cues D, E, and F) were geometrical figures (i.e., a circle, a triangle, and a square, counterbalanced) that appeared at the left-bottom corner of the screen rather than in the spy-radio. Thus, these cues were not associated with the possibility to introduce people in the truck, nor with any outcome. They simply appeared in the screen subject to the identical ITIs as the other cues; therefore, they never appeared at the same time as any of the regular cues but an interval between 3 and 7 s occurred between these types of events. The instructions did not give any information on the existence of these retrieval 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, they had no consequences (and were not reflected in the score panel, nor in the panel that showed the number of people introduced in the truck). The duration of these cues was identical to that of the other cues (i.e., 3 s). The different phases of the experiment, including the test phase, were presented without interruption.

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 the phase in which this discrimination occurs (i.e., Phase 2 in the present experiment). According to this criterion, in the present experiment, responding to B during the last trial in which it is presented during training has to be higher than responding to the last trial of C (e.g., Ortega & Matute, 2000; Pineño et al., 2000). Following this criterion, the data from 1 participant from Group DO and 1 participant from Group SO-Cue2 were eliminated from the analyses. An alpha level of .05 was adopted for tests of statistical significance.

Results

Interference during Training

The results of the two training phases are shown in Figure 1. As can be seen in this figure (left panel) training in Phase 1 proceeded smoothly, showing that all four groups had a good learning level of the first cue-outcome association at the end of that phase: a high number of responses in Groups SO, SO-Cue2 and SO-Novel Cue and a low number of responses in Group DO, as was expected due to the different outcomes that they received.

Most important, groups that received O_1 during Phase 1 showed proactive interference, as they were slower than the group receiving O_2 during Phase 1 (Group DO) in the acquisition of the B-O_1 association during Phase 2 (see Figure 1, right panel). A 4 (Group) x 5 (Blocks of trials) analysis of variance (ANOVA) on responding to B during Phase 2 confirmed these impressions. This ANOVA revealed a main effect of Group, $F(3, 100) = 4.42$, a main effect of blocks of trials, $F(4, 400) = 139.95$, as well as an interaction, $F(12, 400) = 1.10$. Planned comparisons revealed differences on the first block of training trials with B between Group DO and all the groups that received training with the same outcome in Phase 1: with Group SO, $F(1, 100) = 9.18$, with Group SO-Cue 2, $F(1, 100) = 11.41$, and with Group SO-Novel Cue, $F(1, 100) = 3.54$ ($p = .06$ in this case). Differences were also significant in the second block of B trials between Group DO and Group SO, $F(1, 100) = 6.24$, Group SO-Cue 2, $F(1, 100) = 8.46$, Group SO-Novel Cue, $F(1, 100) = 3.96$. This pattern fluctuated thereafter. These results show a proactive interference effect in the acquisition of an association that shares the outcome with a previously trained association.

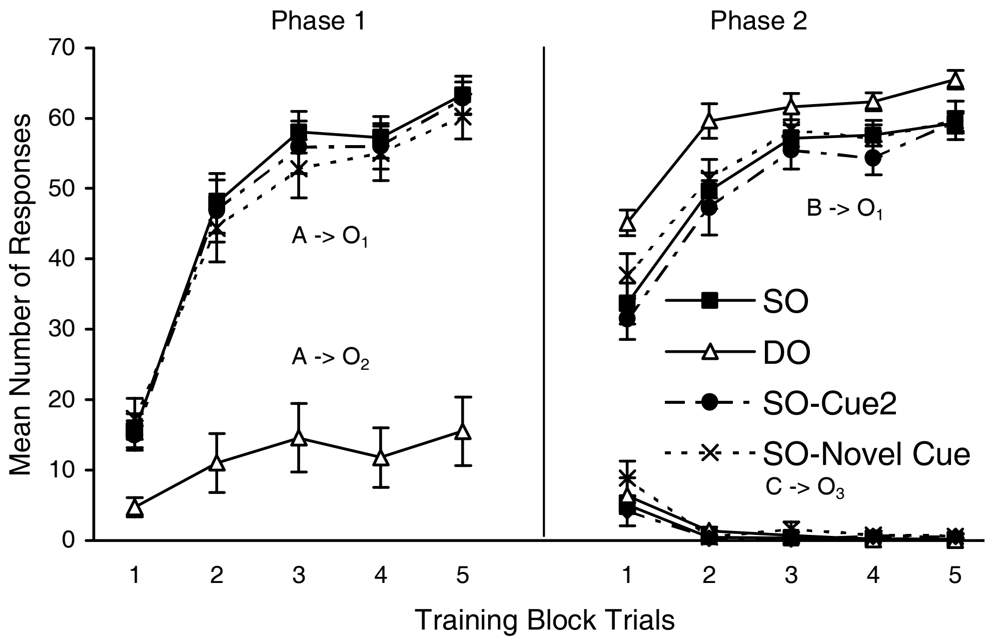

Figure 1. Mean number of responses to A, B and C during training. Error bars represent standard error of the means.

Interference at Test

The next step was to assess interference at the retrieval stage. Figure 2 shows the mean number of responses during testing. As can be seen in this figure, proactive interference was again observed at testing in those groups in which the target association was no more strongly activated than the interfering association at the time of testing. Groups SO and SO-Novel Cue showed weak responding to B at test, compared to Groups DO (in which no interfering association had been trained) and SO-Cue2 (for which nothing potentially disruptive had been presented between the training of the target association and the test phase, which allowed the target association to be strongly activated during testing, due to recency).

In order to confirm these impressions, we performed an analysis of covariance (ANCOVA) on the test of B, including the last block of trials of Phase 2 as a covariate to control for the differential baseline levels of responding at the end of Phase 2 training. This ANCOVA revealed a main effect of group, $F(3, 99) = 4.95$, and planned comparisons showed that responding in Group SO was weak as compared to Group DO, $F(1, 99) = 3.12$, and to Group SO-Cue2, $F(1, 99) = 5.04$. This weak responding in Group SO as compared to Group DO suggests an interference effect due to the presentation of the retrieval cue from Phase 1 before testing. In principle, this can occur either through direct activation of the interfering association by the retrieval cue, or through a reduction in the activation of the recent B-O association. In Group DO, however, in which none potentially interfering association had been trained, the target association could be expressed. Additionally, responding to B remains strong in Group SO-Cue2 because, before testing, these participants were just given one additional presentation of the Phase 2 cue that was being trained along with B. Because there is no break between phases, for Group SO-Cue2 the presentation of the Phase 2 cue is actually one more trial of Phase 2, which allows for a strong activation of the B-O_1 association at the time of testing (because of recency) and, consequently, strong responding to B is observed.

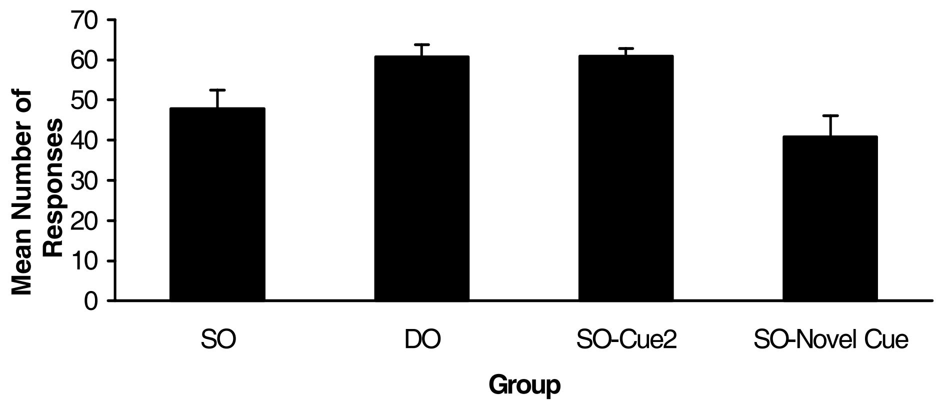

Figure 2. Mean number of responses to B during the test trial. Error bars represent standard error of the means.

Group SO-Novel Cue also showed weak responding to B as compared to Group DO, $F(1, 99) = 8.54$, and to Group SO-Cue2, $F(1, 99) = 11.43$. This suggests that a retrieval cue for the interfering association (e.g., as in Group SO) is not a necessary condition to observe this effect. Instead, the interference effect can be obtained when any disruption between Phase 2 and testing occurs. This disruption reduces the strong activation of the recent B-O_1 association, allowing for the reactivation of the interfering association, A-O_1.

However, it might be possible that the differences found at testing occurred not due to a decrement in responding in Groups SO and SO-Novel Cue, but to an increment in Groups DO and SO-Cue 2. To assess this alternative interpretation, we compared the responding at the last block of trials of Phase 2 with reponding at testing. A 4 (Group) x 2 (Trials: Last Block vs. Test) ANOVA revealed a main effect of Group, $F(3,100) = 5.96$, a main effect of Trial, $F(1,100) = 15.87$, as well as an interaction, $F(3,100) = 4.07$. Planned comparisons revealed differences between the end of Phase 2 and the test trial in Group SO, $F(1,100) = 8.48$ (M = 59.28, SEM = 1.42, and M = 47.86, SEM = 4.66, respectively) and in Group SO-Novel Cue, $F(1,100) = 20.07$, (M = 59.67, SEM = 2.68, and M = 40.80, SEM = 5.34, respectively). On the other hand, differences between the end of Phase 2 and the test trial were not significant in Group DO, $F(1,100) = 1.26$ (M = 65.50, SEM = 1.30, and M = 60.68, SEM = 3.00, respectively) or in Group SO-Cue 2, $F(1,100) = 0.09$ (M = 59.55, SEM = 1.44, and M = 60.95, SEM = 1.77, respectively). Thus, these analyses show that the observed results are a genuine interference effect due to a decrement in responding in Groups SO and SO-Novel Cue.

These results support the hypothesis that, like retroactive interference, proactive interference also occurs when the two associations share a common element and the interfering association is more strongly activated than the target association at the time of testing. In the present case, this was achieved through the presentation of different retrieval cues. Moreover, the interference effect occurred not by means of directly activating the interfering association, but by preventing the target association from being strongly activated and therefore allowing the interfering association to interfere with it at the time of testing.

Discussion

The results of this experiment showed proactive interference at training as well as proactive interference at testing between elementally-trained cues. That is, during both the acquisition stage and the retrieval stage, learning of the firstly trained association can impair responding to the secondly trained association. As we expected, when two associations that share the same outcome are trained, each of both associations is able to interfere with the other one retroactively (as the studies reported in the Introduction showed) and proactively as well, as the present results show.

The interference effect found here results from a failure to retrieve the information concerning the target association (i.e., B-O_1) as a consequence of the previous training of another association that shared the same outcome (i.e., A-O_1). Matute and Pineño (1998a, 1998b) suggested that a cue-outcome association can retroactively interfere with the target association when the two of them share the same outcome and the interfering association is more strongly activated at test. This stronger activation of the interfering association impairs the retrieval of the target association, and consequently weakens responding. Applied to the present experiment on proactive interference, a similar process is observed: Acquisition is slower because the previously trained association (A-O_1) is still active in memory during those early trials of training in which the target association (B-O_1) is being trained. Then, once the two associations have been acquired, proactive interference can again be observed through the activation mechanism at the postacquisition stage if appropriate manipulations are conducted. As has been observed in this experiment, if testing occurs immediately after training on B, good responding to B is observed (i.e., Group SO-Cue2). However, presenting before the test of B a retrieval cue that occurred along with the training of the interfering association, or a novel cue, impairs the retrieval of the secondly trained association (presumably not by directly activating the interfering association, but by preventing the secondly trained association from being strongly activated at testing).

Proactive interference, as well as retroactive interference between elementally-trained cues, cannot be predicted by traditional learning theories because these theories assume that compound training of cues is a necessary condition for interference to occur either during acquisition (e.g., Rescorla & Wager, 1972) or during retrieval (e.g., Miller & Matzel, 1988). However, results on proactive and retroactive interference in predictive learning are consistent with those reported in other interference paradigms. In the paired associate tradition, retroactive and proactive interference could be assessed with either the A-B, C-B or the A-B, A-C paradigms, in which retroactive interference refers to weak recall of the firstly trained association and proactive interference refers to weak acquisition or recall of the secondly trained association (e.g., Bäuml, 1996; Bennett, 1975; Bidoleau & Schlosberg, 1951; Brosgole, 1976; Chandler, 1993; Chandler & Gargano, 1998; Postman, 1971; Postman et al., 1968; Underwood, 1966). The A-B, C-B paradigm parallels interference between elementally-trained cues in predictive learning, both retroactively (Escobar, Matute, & Miller, 2001; Matute & Pineño, 1998a, 1998b;

Ortega & Matute, 2000; Pineño et al., 2000) and proactively (present experiment). On the other hand, interference effects in the A-B, A-C paradigm can be seen as analogous to interference effects between elementally trained outcomes, such as extinction and counterconditioning (e.g., Bouton, 1993; Pineño & Matute, 2000). Moreover, recent research has shown that interference between compounded elements does not only occur between cues trained in compound (e.g., blocking; Kamin, 1968), but also between outcomes trained in compound (e.g., Esmorís-Arranz, Miller & Matute, 1997; Miller & Matute, 1998). In summary, retroactive and proactive interference, both between compound or elemental cues and outcomes, can be observed in a variety of paradigms, and their common characteristics suggest the viability of a common explanation.

The present results, along with those on retroactive interference (e.g., Escobar, Matute, & Miller, 2001; Matute & Pineño, 1998b; Pineño et al., 2000) suggest that (1) in the absence of retrieval or contextual cues the most recently trained association can interfere with the expression of the firstly trained association, and (2) if contextual, retrieval, or even novel cues disrupt the effect of recency, the firstly trained association tends to prevail and can impair retrieval of the most recent association (conversely, in the case of retroactive interference, the interference effect is attenuated, rather than increased, when the test phase is separated from the training phase; see Pineño et al., 2000).

A similar mechanism for interference has also been proposed by Chandler and Gargano (1998) in relation to forced-choice recognition tests. They suggested that retroactive interference effects occur because, by default, “recent items are stronger and therefore more likely to be sampled at the expense of the target” (p. 227). The present results are consistent with this view and extend it by showing that older items, rather than recent items, tend to prevail when there is something (e.g., a novel, nontarget cue) that disrupts the continuum between training and testing.

This hypothesis of the strongly activated association can be seen as an extension of Bouton´s theory (1993, 1994) concerning interference between outcomes. In studies of interference between outcomes, two associations are also trained in different phases. However, instead of training two different cues with the same outcome, a single cue is paired with two different outcomes in different phases (e.g., extinction and counterconditioning). That is, a cue is paired with one outcome in Phase 1 (i.e., A-O_1), and with no outcome or with a different outcome in Phase 2 (i.e., A-no O or A-O_2). In this case, behavior appropriate to Phase 2 is normally observed at testing, due to recency (i.e., retroactive interference). However, if the effects of recency are overcome (e.g., through a retention interval introduced before testing), behavior appropriate to Phase 1 is observed (i.e., spontaneous recovery, Pavlov, 1927; Bouton, 1993). Moreover, if a nontarget cue that was present during a certain phase of the study is presented before testing, subjects will show behavior during testing that is appropriate to that phase (Brooks, 2000; Brooks & Bouton, 1993). Finally, if we take into account that the memory of the first association in which an event is involved is the most likely to manifest when the memory of the second one is not strongly activated (e.g., as in spontaneous recovery; Bouton, 1997), it could be argued that interference effects occur not by the direct activation of the interfering association, but by the prevention of the target association from being strongly activated, which therefore allows the interfering association to interfere with it at testing.

The present results add support to the idea that this approach can be applied to both retroactive and proactive interference, both between cues and between outcomes (e.g., Matute & Pineño, 1998a). Indeed, interference between elementally-trained cues and interference between elementally-trained outcomes can be seen as symmetrical effects: Two different cues are paired with the same outcome or one cue is paired with two different outcomes. Further testing of the particular account that we have provided here will decide about its adequacy.

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