The role of the number of cues on retroactive interference in human predictive learning

Ana García-Gutiérrez & Juan M. Rosas[*]

University of Jaén (Spain)

Two experiments explored retroactive interference in human predictive learning. The name of a food was paired first with a gastric illness (A+), and then paired with a different gastric illness that was incompatible with the first one (A*). Experiment 1 presented three additional cues. C was followed by no outcome (C-). B was followed by * during the first phase, and then it was not presented during the second phase. Finally, D was presented only during the second phase, and it was followed by +. Under these conditions, retroactive interference was found as participants judging that A was followed by the second outcome, rather than by the first one. However, this treatment was generalized to B. This generalization was eliminated in the second experiment when the number of cues was increased, so that participants had the opportunity to learn that some cues may have not changed their meaning across phases. These results suggest that to find a clear effect of retroactive interference is needed to give participants the opportunity to learn that the meaning of different cues is independent of one another.

Retroactive interference techniques have shown to be an important tool to explore different aspects of memory in human and nonhuman animals (e.g., Bouton, 1993; Rosas, Vila, Lugo, & López, 2001; Underwood, 1957). The aim of the experiments reported in this paper was to find a retroactive interference procedure that could be used on the study of retrieval of the information in causal learning, exploring the conditions that would lead to interference in that situation.

Our starting point was the technique used by Rosas et al. (2001). Their procedure seemed to produce retroactive interference, but it did not allow for recording the response throughout the training. Basically, the procedure used by Rosas et al. (2001) consisted on the presentation of pairings between a fictitious medicine (cue) and a side effect (outcome) that was hypothetically

caused by the medicine, so that participants would end the acquisition phase judging that the cue was followed by the outcome (A+). Subsequently, the cue was followed by a different incompatible outcome (A*), so that by the end of training participants would end judging that the cue was a better predictor of the second outcome than the first one, showing a retroactive interference effect. Estimations of participants about the causal cue-outcome relationships were requested at the end of the acquisition and interference phases. Retroactive interference was reported with this procedure. However, recording judgments at the end of each phase does not allow knowing how learning developed.

This problem had been corrected in the work conducted by Paredes-Olay and Rosas (1999). They used an extinction procedure where a fictitious medicine was first paired with a hypothetical side effect, and then presented alone. Predictive judgments were recorded at every trial. These authors replicated some of the effects reported by Rosas et al. (2001) in a situation where recording trial-by-trial changes in judgments allowed for a better evaluation of the effects of context change upon acquisition and extinction.

Any of these procedures may be useful to study retroactive interference. However, pilot experiments conducted in our laboratory have shown that both techniques have important limitations. In both cases the cues used were names of fictitious medicines. The names were unusual, limiting the number of different cues that could be used within the same experiment. When more than three cues were used, participants reported to be confused, and they behaved randomly independently of the treatment received by each cue. The aim of the experiments reported on this paper was to find a technique that would allow for studying retroactive interference in a situation where multiple cues and outcomes were used. Finding this kind of procedure would allow for a better control of the experience with the outcomes along the experiment. Additionally, the experiments were conducted so that developing of retroactive interference along training could be observed, recording the participants' response every few trials.

EXPERIMENT 1

The aim of Experiment 1 was to develop an interference technique to study retroactive interference in human predictive learning that would allow for the use of multiple cues, and for recording the developing of retroactive interference throughout the experiment.

Common food names were used as cues. There is evidence in the literature showing that employing food names allows for the use of multiple cues in the same experiment without confounding the participants (e.g., Dickinson & Burke, 1996). Two different gastric illnesses were used as outcomes.

The design of the experiment is presented in Table 1. During acquisition, two food names were followed consistently by two different gastric illnesses (A+, B*), while another food name was followed by no

outcomes (C-). During the retroactive interference phase, the outcome that followed one of the cues was changed (A*), other cue (B) was not presented, and C continued being followed by no outcomes. A new cue was introduced during this phase followed by the alternative outcome to the one that followed A (D+). This allowed for equating outcome exposure throughout the training.

Table 1. Design of Experiment 1.

Acquisition	Retroactive interference
A+, B*, C-	A*, D+, C-

Note— A, B, C, and D: Garlic, cucumber, corn, and caviar. + & *: Diarrhea and constipation. Cues and outcomes were counterbalanced across participants. Cue-outcome relationships were recorded before acquisition, and after each 4-trial block of training (three on each phase) for all the cues.

Retroactive interference should show as the participants judging A as followed by its second outcome (*) rather than by the first one (+) by the end of the experiment. B did not receive the interference treatment, thus its evaluation was not expected to change throughout the training. C was a distractor cue. It was never related to any outcome and it was expected to show neutral evaluations throughout the training. Finally, D was expected to show neutral evaluations during the acquisition phase, increasing the relationship between D and + during the retroactive interference training.

METHOD

Participants and apparatus. Sixteen undergraduate students of the University of Jaén participated in the experiment. They were between 18 and 25 years old and had no previous experience with this task. Approximately 75% were women, and 25% were men. Participants received course credit for their participation in the experiment.

The participants were run individually in three adjacent isolated cubicles. Each cubicle had an IBM compatible personal computer on which the task was presented. The procedure was implemented using the program SuperLab Pro (Cedrus Corporation).

Diarrhea and constipation were counterbalanced as outcomes + and *. Cues (food names) were selected as neutral in their relationship with the outcomes by a questionnaire filled by 120 students of the University of Jaén. The questionnaire included 90 common food names. Using a Likert type scale, students were requested to judge in what degree they considered that the ingestion of each food would be followed by constipation (-5), nothing (0) or diarrhea (+5). The selected cues were those with the mean closer to zero, and the smallest standard deviation. Selected food names (mean and standard

deviation are presented within brackets) were Cucumber (-0.04, 1.66), Garlic (-0.15, 1.38), Caviar (-0.13, 1.57), and Corn (-0.13, 1.83).

Two different contexts, X and Y, were used in this experiment. They were the names of two fictitious restaurants ("The Canadian cabin", and "The Swiss cow"). The name of the restaurant "The Canadian cabin" was written in capital cobalt blue within a turquoise blue rectangle. The name of the food appeared in capital letters in a cobalt blue font. The name of "The Swiss cow" restaurant appeared within a yellow oval. The rest of the text appeared in black fonts. Screen background was white. Contexts were counterbalanced across participants, but they were not manipulated in this experimental series.

Procedure. Once participants entered the cubicle and sat in front of the computer, the experimenter asked them to pay attention to the instructions that they were about to receive, and left the room. Instructions were presented in different screens, written with a black font against a white background. Participants controlled the transition between screens by pressing the space bar. Before starting with the experiment, a screen was presented to inform participants about the general features of the experiments. Following this screen, the specific instructions for the experiment were presented:

(1st screen). "Last developments in food technology lead to chemical synthesis of food. This implies a great advantage as the cost is very low, and it is easy to store and transport synthetic food. This revolution in the food industry may solve hunger in third world countries. (2nd screen). However, it has been detected that some foods produce gastric problems in some people. For this reason we are interested in selecting a group of experts to identify the foods that lead to some type of illness, and how it appears in each case. (3rd screen). You are about to receive a selection test where you will be seeing the files of persons that have ingested different foods in a specific restaurant. You will have to indicate whether gastric problems will appear. Your response will be random at the beginning, but you do not worry, little by little you will become an expert. Call the experimenter before continuing."

Throughout the experiment two types of screen were presented. One of them was devoted to record trial-by-trial predictive judgments (which outcome is going to follow the ingestion of this food?). The second screen was devoted to record probability judgments (which is the probability of this food causing this outcome?).

On the top of the predictive judgments screen the sentence "A person ate in restaurant... (name of the restaurant)" appeared. In the center of the screen the sentence "this person ate... (name of a food) and suffered..." appeared. Text was written on Times 16 font (black), Times 18 for the name of the restaurant, and Times 24 for the name of the food (written in cobalt blue). The names of the outcomes were presented at the bottom of the screen. Diarrhea was written in red, Constipation was written in pink, and Nothing

was written in green. Participants had to select on the keyboard one of the numbers that appeared next to each option (1, 2, and 3, respectively), and then press the space bar to go to the following screen. Immediately after this screen, and independently of the chosen option, participants received a 1500 mlsec feedback indicating the problem the person had (diarrhea, constipation or nothing). Intertrial interval was 1500 mlsec and it was indicated by a screen with the sentence "Loading file of… (a randomly chosen full name)." Person names were different on every trial to give the participant the impression that each file (trial) corresponded to a different person.

The second type of screen was devoted to record the probability judgments about the relationship between the ingestion of a kind of food, and the outcomes that it may produce. On the top of the probability judgments screen there was a sentence that read "this person ate at restaurant... (name of the restaurant)." In the middle of the screen it was written "Indicate the probability that a person that has eaten... (name of a food) presents... (name of an illness)." Below that sentence there was a 0 to 9 scale, represented by a line divided in nine segments, each with a number below. On top of numbers 0, 3, 6, and 9, the labels "Nothing", "Little", "Quite", and "A lot" were written in bold font. Except for the name of the food that was written in cobalt blue capitals, the rest of the text was written in black regular fonts. Background screen was white. The experiment was conducted in two phases. The design is presented in Table 1.

A test about the relationship between each cue and each outcome was conducted before the beginning of training, using the probability judgments screen as described above. Eight different probability judgments were consecutively requested, one for each cue-outcome possible relationship. Question order was counterbalanced across participants.

Acquisition. Participants were exposed to three 12-trial blocks, with 4 trials of each combination A+, B*, and C- randomly intermixed in each block. Predictive judgments were recorded on a trial-by-trial basis. A probability judgment about the relationship between each cue (A, B, C, and D) and each outcome (+ and *) was requested at the end of each block of trials. This test was identical to the one received by participants before the beginning of training, except for the question order that was counterbalanced across blocks and participants.

Retroactive interference. This phase was identical to the previous one with the exception that A* trials substituted A+ trials, B was not presented, and a new food, D, was paired with +. In summary, the meaning of A was changed, but the experience with the different outcomes was kept constant throughout phases. Predictive and probability judgments were requested the same way as it was done during acquisition.

Dependent variables and statistical analysis. Predictive judgments were recorded for each cue. Probability judgments were recorded for each cue-outcome combination. Only probability judgments are reported to simplify the presentation of the data (predictive judgments were either redundant to probability judgments, or not informative with respect to the aims of the experiment). We calculated the difference between percentage ascribed to O1 and O2 for foods A, and B in each participant. Note that O1 is + for cue A, and * for cue B. Meanwhile, O2 is * for A, and + for B –B had no second outcome, thus, B's O2 was the outcome that was not related to the cue. Positive differences indicated that participants rated the cue as causing O1 rather than causing O2. Negative differences indicated that participants rated the cue as causing O2 more than O1. A difference of zero indicated that participants rated the stimulus as causing O1 as much as O2. Differences close to zero are ambiguous. They may reflect high, intermediate, or low ratings for both outcomes. To avoid this ambiguity, we present the critical final test ratings for both outcomes separately in Table 2. Differences were evaluated with analysis of variance (ANOVA). Planned comparisons were conducted by using the methods discussed by Howell (1987, pp. 431-443). The rejection criterion was set at $p < .05$.

Table 2. Probability judgments for O1 and O2 during the final test of acquisition (Acq) and retroactive interference (RI) in Experiments 1 and 2.

Experiment		A		B		C		D	
1		Acq	RI	Acq	RI	Acq	RI	Acq	RI
	O1	7.8	1.9	7.4	2.9	0.6	1.9	1.6	6.1
	O2	0.9	6.8	0.5	3.1	1.0	1.3	2.7	2.8
2									
	O1	8.5	1.2	6.8	7.4				
	O2	1.5	7.3	1.1	0.7				

Note— A, B, C, and D: Garlic, cucumber, corn, and caviar counterbalanced across participants. For A, B, and D, O1 represents the outcome with which the cue was related first. O2 represents the alternative outcome. For the cue that was never paired with the outcome (C), it was arbitrarily decided that + would play the role of O1, and * would play the role of O2.

RESULTS AND DISCUSSION

Mean differences between the judged probability of cues causing O1 and O2 in the test conducted before acquisition was -0.62 and -1.31 for cues A and B, respectively. This difference was not statistically significant, $F(1, 15) = 0.78$ ($MS_e = 4.84$).
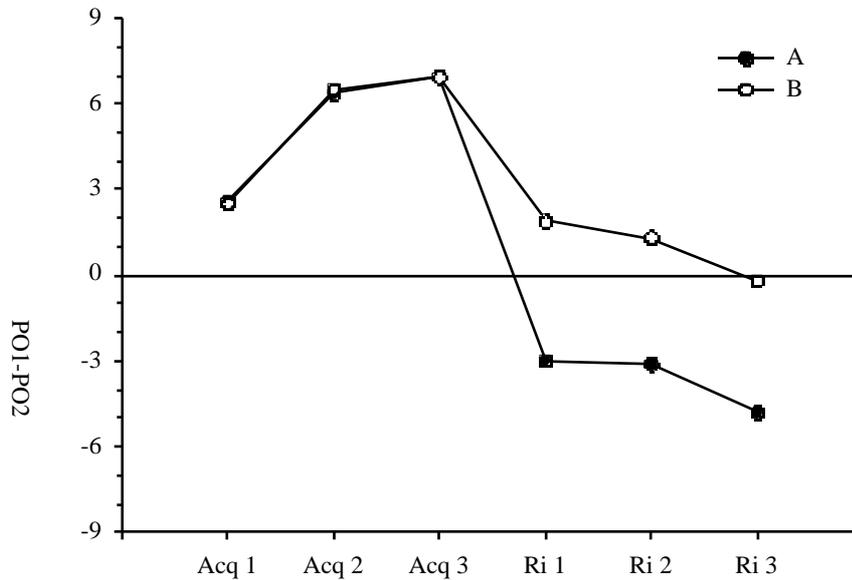
Figure 1. Mean difference between the judged probability of cues A and B causing O1 and O2 in the tests conducted during acquisition (Acq) and retroactive interference (Ri) phases in Experiment 1. O1 represents the first outcome related to the cue (+ and * for A and B, respectively). O2 represents either the second outcome related to the stimulus (* for the cue A), or the outcome that was never paired with it (+ for the cue B).

The main results of this experiment are presented in Figure 1. This figure presents the mean difference between the judged probability of cues A and B causing O1 and O2 in the test conducted after each of the three 4-trial blocks of acquisition and retroactive interference. Mean differences were positive and increasing throughout the acquisition phase, independently of the cue. During the retroactive interference phase, differences become increasingly negative for A, while approaching zero for B. Statistical analysis confirmed these impressions. A 2 (cue) x 2 (phase) x 3 (test trial) ANOVA found a significant main effect of cue, $F(1, 15) = 12.53$ ($MS_e = 17.63$), phase, $F(1, 15) = 36.32$ ($MSe = 54.75$), and test trial, $F(1, 15) = 5.91$ ($MS_e = 9.89$). Phase x trial interaction, $F(1, 15) = 14.82$ ($MS_e = 13.20$), and cue x phase interaction, $F(1, 15) = 18.76$ ($MS_e = 12.47$) were also significant. No other interaction was statistically significant, $Fs<1$.

Subsequent analysis conducted to explore the phase by trial interaction found that the simple effect of trial was statistically significant during acquisition, $F(2, 29) = 7.29$ ($MS_e = 13.20$), but it was not significant during retroactive interference, $F<1$. These results indicate that, in general, participants reached the asymptote more rapidly during retroactive interference than during the acquisition phase. On the other hand, exploring the cue by phase interaction revealed that the simple effect of cue, that was not significant during acquisition, $F<1$, it was significant during retroactive interference, $F(1, 29) = 30.22$ ($MS_e = 12.47$), showing that the retroactive interference treatment affected more the cue that received it, A. However, the simple effect of phase was significant for both, A, $F(1, 21) = 53.37$ ($MS_e = 12.47$), and B, $F(1, 21) = 12.77$ ($MS_e = 12.47$).

This last result indicates that the interference treatment received by A also affected the cue that was not presented during the interference phase (B). This result was further confirmed by the comparison between the last test of acquisition and the last test of interference. The difference found there was statistically significant for both cues, $Fs(1, 29) = 62.81$, and 26.96 ($MS_e = 12.47$), for A and B, respectively. Thus, retroactive interference also affected the control cue (B), even though this cue was not presented during the interference phase.

Differences for C and D were calculated by subtracting judgments to * from judgments to +. There were no reasons to expect differences between the two judgments during the acquisition phase (note that C was presented without outcome, and D was not presented). During the retroactive interference phase + was D's O1, expecting the differences to become positive. Mean differences were close to zero on the pre-acquisition test (-0.37, and –0.12 for C, and D, respectively). Mean differences did not change throughout the training for C (1.12, -0.5, -0.37, and 0.06, 0.12, 0.68 for each of the three blocks of acquisition and interference, respectively). However, mean differences for D, while remaining near zero during acquisition (0.00, -1.18, and –1.12 for each of the acquisition blocks, respectively), slightly increased during the retroactive interference phase (2.18, 2.75, and 3.31 for each block of interference, respectively). A 2 (cue) x 2 (phase) x 3 (test trial) ANOVA confirmed these appreciations. It found a significant main effect of phase, $F(1, 15) = 8.66$ ($MS_e = 19.26$). The cue x phase, $F(1, 15) = 5.97$ ($MS_e = 22.03$), and phase x test trial, $F(1, 15) = 10.72$ ($MS_e = 1.98$) interactions were significant. No other main effects or interactions were statistically significant, $Fs <1$.

Subsequent analysis conducted to explore the cue by phase interaction found that the simple effect of cue, that was not significant during acquisition, $F(1, 29) = 2.73$ ($MS_e = 22.03$), it was significant during the retroactive interference phase, $F(1, 29) = 6.67$ ($MS_e = 22.03$). On the other hand, the simple effect of phase was statistically significant for D, $F(1, 41) = 21.62$ ($MS_e = 22.03$), but it was not significant for C, $F < 1$. That is, mean differences for D increased between acquisition and interference phases. There were no differences on the estimations given by participants to C and D during acquisition, when C was followed by no outcomes, and D was not

presented. During interference, mean differences reflected the treatment received by the cues, they become positive for D (the one paired with the outcome) while remained close to zero for C.

The analysis conducted to explore the phase by trial interaction found that the simple effect of phase, that was not significant in trial 1, $F < 1$, it was significant in trials 2 and 3, $Fs\ (1, 21) = 10.75$, and $15.63\ (MS_e = 1.98)$, respectively. Meanwhile, the simple effect of trial was not significant independently of the phase, $Fs\ (2, 21) = 2.55$, and $1.49\ (MS_e = 1.98)$, for acquisition and interference, respectively.

Table 2 presents the mean judgments for the relationship between each cue and each outcome separately on the tests conducted at the end of acquisition and retroactive interference phases. These results confirm the ones reported with the difference scores clarifying the ambiguity of differences of zero for cues B, C, and D. Retroactive interference appeared as a full reversal in judgments to A between acquisition and retroactive interference. Differences of zero for C reflected low scores on both, C+ and C* relationships. The same was true during the acquisition phase for D. However, during the retroactive interference phase, judgments to the D-O1 relationship increased, while judgments to the D-O2 relationship remained close to zero. The most interesting data here correspond to the judgments given to B during retroactive interference. The differences of zero in that cue were due to a large decrease on the judged relationship between B and O1, $F\ (1, 15) = 22.50$ $(MS_e = 7.20)$, combined with a moderate increase on the judged relationship between B and O2 with respect to the acquisition phase, $F\ (1, 15) = 8.63$ $(MS_e = 3.39)$.

In summary, these results indicate that the participants learned without problems the specific food-outcome relationships established during acquisition, so that by the end of this phase they were able to attribute each outcome to the cue with which it was paired. Acquisition performance was increasing as experience with the specific cue-outcome combination increased. However, when the outcome of the cue A was changed during the retroactive interference phase, this change affected the judgments to the cue that did not receive interference treatment (B). This result was somewhat unexpected.

These results may have been prompted because the outcomes used in this experiment were quite similar. As both outcomes were gastric illnesses, there is a possibility of participants coding the outcomes as "gastric illness", instead of diarrhea and constipation. This could explain why participants judge similarly the relationship between B and each outcome by the end of the retroactive interference phase. However, if that were the case, the same generalization should have affected to cues A, and D, leading participants to judge equally that A and D were followed by the two outcomes. This was not the case, suggesting that participants had no problem to discriminate between the various cue-outcome relationships throughout the training.

An alternative explanation of these results uses generalization in a more standard way (e.g., Spence, 1936). One possibility would be that the interference suffered by A would be generalized to B. However, it should be

noted that the outcome paired with A during retroactive interference (*) was actually B's O1. Thus, any generalization from A to B should have led participants to strengthen the relationship between B and O1, rather to the observed decrease on that relationship. Another source of generalization during the interference phase would come from D. As B was substituted by D, and paired with + (B's O2), participants could have generalized the outcome of the cue that plays the role of B during the interference phase (D) to B, changing its evaluation.

Alternatively, there is a feature of the design that may account for the effect of interference found in B. The experiment was designed so that the experience with the outcomes would be equated throughout training. This allowed for a new source of interference, besides the interference found between the outcomes of cue A. Cue B was followed by an outcome during acquisition. Then, another cue (A) was followed by the same outcome during the interference treatment. There have been some reports in the literature showing that interference can also be found when two different cues are sequentially paired with the same outcome, as it was the case here (Matute & Pineño, 1998a; Pineño, Vegas, & Matute, 2003). It is possible that A* pairings would have decrease judgments about the B* relationship. It is not clear why this should have increased the relationship between B and the outcome that it was never paired with it (+). However, it should be noted that this increase was numerically smaller than the decrease found in the B* relationship, leaving open the possibility of explaining these results as caused by interference between two cues paired with the same outcome. This interpretation implies that the retroactive interference found in the cue A could be the result of interference between outcomes (A+|A*) added to interference between cues (A+|D+). Previous reports on retroactive interference in causal learning did not face this problem, as the experience with the outcomes along the experiment was not equated (e.g., Rosas et al., 2001).

An even simpler explanation for these results would come from the fact that cue B was not presented during interference. It is possible to claim that requesting the judgments in the absence of B, could have confound participants about B's outcome. The specific cue-outcome relationship could have been forgotten, or interfered by the new cue-outcome relationships established during retroactive interference.

Independently of whether generalization, cue competition or forgetting was the cause of the results with respect to B, it seems clear that the procedure of retroactive interference should be polished to be able to control for the experience with the outcomes along phases, without sacrificing the specificity of the interference treatment. This was the aim of Experiment 2.

EXPERIMENT 2

Experiment 2 was conducted with the aim of solving the problems on detecting retroactive interference found in Experiment 1. Additionally, it was conducted to separate between the different interpretations of the change on estimations to the control cue in Experiment 1.

The design of this experiment is presented in Table 3. Two new cues were included, egg and tuna fish, related with outcomes + and *, respectively. This relation did not change throughout the training. Assuming that the cause of the change on the judgments to B during interference may be due to participants not considering the meaning of B and D independently, the design of this experiment ensured that participants could learn that the meaning of a cue would not necessarily be changed when the meaning of other cue changes. We expected that this change would help participants to learn about the meaning of the cues independently, decreasing the possibility of generalization.

Table 3. Design of Experiment 2.

Acquisition	Retroactive interference
A+, B*, C-, E+, F*	A*, D+, C-, E+, F*

Note— A, B, C, and D: Garlic, cucumber, corn, and caviar, counterbalanced. E & F: Eggs and tuna fish, respectively. + & *: Diarrhea and constipation, counterbalanced. Cue-Outcome relationships were recorded before acquisition, and after each 4-trial block of acquisition and interference for cues A and B (three times on each phase).

On the other hand, if the results found in Experiment 1 with respect to cue B were the consequence of competition between cues paired with the same outcome (e.g., Matute & Pineño, 1998a, b), the inclusion of new cues should, if anything, increase cue competition, leading to a result similar to the one found in Experiment 1. Similarly, increasing the number of cues should, if anything, facilitate forgetting of B's outcome.

METHOD

Participants and apparatus. Twelve students with the same characteristics described in Experiment 1 participated in the experiment. Apparatus were the same used in Experiment 1, except for the use of two new cues, Eggs (0.03, 1.83) and Tuna fish (0.12, 1.01) –Numbers within brackets represent the mean and standard deviation found in the questionnaire used to select the cues, described above.

A. García-Gutiérrez & J.M. Rosas

Procedure. Procedure was identical to the one used in Experiment 1, except for what follows. Two new cues were added, Eggs (E) and Tuna fish (F). They were related to the same outcomes (E+, F*) throughout the two phases of the experiment. The number of trials E+ and F* was the same that with any other combination (three 4-trial blocks on each phase). With the aim of simplifying the task for participants, probability judgments were requested only for cues A and B throughout the experiment. Thus, four different probability judgments were consecutively requested, one for each cue-outcome possible relationship (A+?, A*?, B+?, and B*?). Question order was counterbalanced across participants and tests.

RESULTS AND DISCUSSION

Mean difference between the judged probability of cues causing O1 and O2 in the test conducted before acquisition was -0.50 and 1.40 for cues A and B, respectively. Differences between these cues were not significant, $F (1, 11) = 1.21$ ($MS_e = 18.22$).

Figure 2 presents the mean difference between the judged probability of cues A and B causing O1 and O2 in the test conducted after each of the three 4-trial blocks of acquisition and retroactive interference. Mean differences were increasingly positive during acquisition, independently of the cue. However, during the retroactive interference phase, mean differences became increasingly negative for A, while remained positive and constant for B. Statistical analysis confirmed these impressions. A 2 (cue) x 2 (phase) x 3 (test trial) found a significant main effect of cue, $F (1, 11) = 29.01$ ($MS_e = 39.45$), phase, $F (1, 11) = 126.72$ ($MS_e = 7.99$), and trial, $F (2, 22) = 3.96$ ($MS_e = 7.99$). Most important, the cue x phase interaction, $F (1, 11) = 58.24$ ($MS_e = 18.69$), and phase by trial interaction, $F (2, 22) = 3.78$ ($MS_e = 9.85$) were significant. No other main effect or interaction was statistically significant, $Fs<1$.

Subsequent analysis conducted to explore the cue by phase interaction found that the simple effect of cue, that was not significant during acquisition, $F<1$, it was statistically significant during retroactive interference, $F (1, 19) = 76.81$ ($MS_e = 18.69$). Additionally, the simple effect of phase was significant only for A, $F (1, 7) = 84.46$ ($MS_e = 18.69$), not being significant for B, $F<1$. These results show that interference reversed the judgments given by participants to the cue A, leaving unchanged the judgments given to the cue B.

With respect to the exploration of the phase by trial interaction, the simple effect of trial was significant during acquisition, $F (2, 32) = 7.44$ ($MS_e = 18.69$), but it was not significant during retroactive interference, $Fs < 1$. The lack of trial effect during retroactive interference may reflect both, the quick development of retroactive interference for cue A combined with the lack of changes on the judgments to B.

Similarly to what it was done in Experiment 1, complementary analyses were conducted to compare performance at the end of acquisition with performance at the end of retroactive interference on each cue. There was a

significant change on performance in A, $F(1, 19) = 32.24$ ($MS_e = 18.69$), but no changes on performance between the end of the two phases were detected in B, $F < 1$. This result confirms our conclusion, suggesting that the interference treatment only affected the cue that received it.
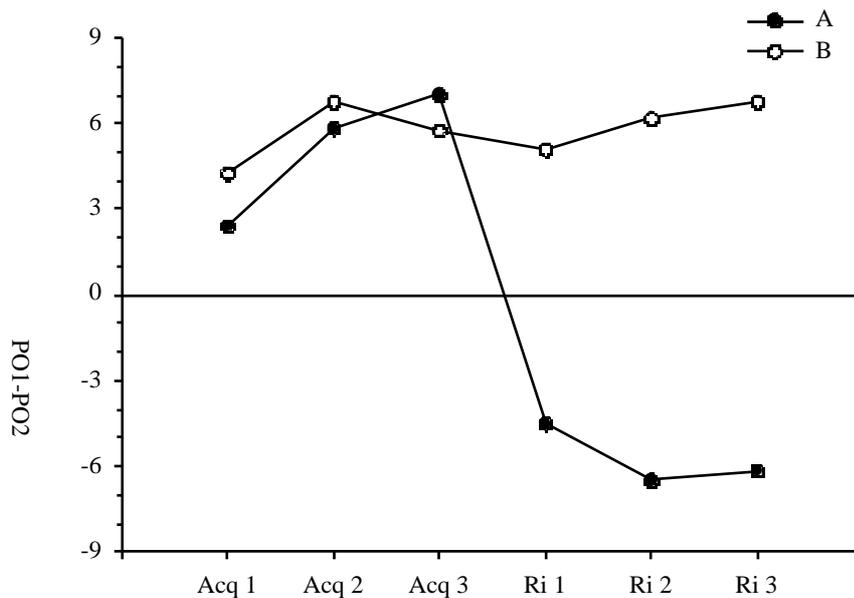

Figure 2. Mean difference between the judged probability of cues A and B causing O1 and O2 in the tests conducted during acquisition (Acq) and retroactive interference (Ri) phases in Experiment 2. O1 represents the first outcome related to the cue (+ and * for A and B, respectively). O2 represents either the second outcome related to the stimulus (* for the cue A), or the outcome that was never paired with it (+ for the cue B).

Table 2 presents the mean judgments for the relationship between each cue and each outcome separately on the tests conducted at the end of acquisition and retroactive interference. These results confirm the ones reported with the difference scores. Retroactive interference appeared as a full reversal in judgments to A between acquisition and retroactive interference. Judgments to B remained unchanged, being high for B-O1, and low for B-O2 throughout the phases.

In summary, the retroactive interference treatment led participants to reverse their judgments about the outcomes of the cue that had received the interference treatment (A). Unlike the results found in Experiment 1, this

treatment did not affect performance to the cue that did not receive interference (B), suggesting that the role of cue competition on the results found in Experiment 1 is small, if any. Similarly, the lack of changes on B's evaluation when the number of cues was increased in Experiment 2, rends unlikely the interpretation of the results of Experiment 1 in terms of forgetting of B's outcome.

These results seem to suggest that the change on the judgments to B during the interference phase found in Experiment 1 may be due to participants generalizing to B the outcome of the cue that played B's role during the interference phase. However, this is an indirect test of this hypothesis, and our conclusion to that respect should be taken just as a reasonable possibility.

At any rate, this procedure seems to be adequate to find retroactive interference in human predictive learning, having the important advantage with respect to other procedures previously used in the literature of allowing for equating the experience with the outcomes throughout the training.

GENERAL DISCUSSION

These experiments were conducted with the aim of finding a procedure that would allow for the study of retroactive interference in human predictive learning. Experiment 1 found some evidence of retroactive interference, as the change on the meaning of the cue produced a drastic change on its evaluation by participants. However, this change was accompanied by a parallel change on a cue that did not receive the interference treatment. It was hypothesized that this result may have been due to the fact that the design of the experiment allowed for competition between cues related to the same outcome (Matute & Pineño, 1998a, b; Pineño et al., 2003). Alternatively, participants may have forgotten the meaning of the cue that did not suffered interference, given that this cue was not presented during the retroactive interference phase. Finally, because of the simple design of the experiment, participants may have generalized the meaning of the cue added during the interference treatment (D) to the control cue. The fact that the added cue substituted the control cue during the interference treatment could have facilitated this generalization. This possibility was prevented in Experiment 2 by adding new cues equally related to the outcomes, but keeping the same meaning throughout the experiment. Under this condition, the change on the meaning of the cue that received the interference treatment did not affect judgments to the control cue, leading to a clean retroactive interference effect.

The retroactive interference procedure designed in these experiments has several advantages with respect to the ones previously used in the literature. Rosas et al. (2001) used a retroactive interference procedure that seems to produce clear retroactive interference effects. However, their procedure does not allow for recording of performance throughout training. The technique used in these experiments could allow for observing how acquisition and interference develops. However, it should be noted that

retroactive interference developed very fast in these experiments, probably due to the fact that there was a perfect cue-outcome contingency within each phase. It is likely that reducing the level of cue-outcome contingency throughout training would conduct to slower developing of acquisition and interference, allowing for studying learning effects with this procedure.

On the other hand, previous experiments on retroactive interference had used fictitious names of medicines as cues (Paredes-Olay & Rosas, 1999; Rosas et al., 2001; Vila & Rosas, 2001, 2002a, b), limiting the number of cues that could be used within the same experiment without getting participants confused. This limitation made difficult to control for some important features of the experiments when the effects of different manipulations upon retroactive interference were studied (e.g., Rosas et al., 2001). For instance, when the effects of context change upon interference are evaluated, the different contexts used should be equated with respect to their relationship with the outcomes. Otherwise, data obtained may be influenced by the associative value of the context. This possibility can be precluded using the design employed on these experiments. In fact, comparing the results of Experiments 1 and 2, it seems that increasing the number of cues improved, rather than impaired, detection of retroactive interference. Additionally, these experiments extend the results obtained by Rosas et al. (2001) to a within subject procedure.

It should be noted that the design employed in these experiments could confound two types of interference, interference between outcomes, when the different outcomes are predicted by the same cue (e.g., Rosas et al., 2001), and interference between cues, when different cues predict the same outcome (Matute & Pineño, 1998b; Pineño et al., 2003). In fact, as noted above, it is possible to claim that the disruption on judgments to cue B on Experiment 1 was due to interference between cues (A predicted the same outcome during retroactive interference that was predicted by B during the acquisition). However, the fact that this disruption on the cue that did not suffer interference between outcomes was not found in Experiment 2 —where the number of cues was increased, and thus, interference between cues should have increased accordingly— questions the contribution of interference between cues to these results.

At any rate, there is no way to fully eliminate the possibility of interference between cues with our results. It seems clear that the contribution of that kind of interference to our results should be small, if any, but we cannot discard completely the possibility of its existence. Unfortunately, it seems difficult to avoid this confound if we want to keep the experience with the outcomes equated throughout different phases and contexts at the same time. The design ultimately used on the experiments devoted to study retroactive interference on human predictive learning would depend on which part of the control is less problematic to sacrifice. The technique presented here has the advantage of allowing for increasing the number of cues without eliminating the effect of retroactive interference, increasing that way the possibility of controlling different aspects of the procedure that may affect the presentation of interference, and its attenuation.

RESUMEN

El papel del número de claves sobre la interferencia retroactiva en aprendizaje predictivo humano. Dos experimentos exploraron la interferencia retroactiva en aprendizaje predictivo humano. El nombre de un alimento se emparejó primero con un trastorno gástrico (A+) y después con otro trastorno diferente incompatible con el primero (A*). El Experimento 1 presentó tres claves adicionales. La clave C no fue seguida por consecuencias (C-). La clave B fue seguida por * durante la primera fase, y después no se presentó durante la segunda. Finalmente, la clave D se presentó sólo durante la segunda fase seguida por la consecuencia +. Bajo estas condiciones, la interferencia retroactiva se encontró con los participantes juzgando que A iba seguida por su segunda consecuencia, en lugar de ir seguida por la primera. Sin embargo, este tratamiento se generalizó a la clave B. En el segundo experimento esta generalización se eliminó al incrementar el número de claves, de modo que los participantes tuvieran la oportunidad de aprender que algunas claves podían tener el mismo significado en las distintas fases. Estos resultados sugieren que para encontrar un efecto claro de interferencia retroactiva es necesario dar a los participantes la oportunidad de aprender que el significado de distintas claves es independiente.

REFERENCES

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

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

Howell, D. C. (1987). *Statistical methods for psychology*. Boston: Duxbury Press.

Matute, H. & Pineño, O. (1998a). Cue competition in the absence of compound training: Its relation to paradigms of interference between outcomes. In D. L. Medin, *The Psychology of Learning and Motivation, 38*, (45-81). New York: Academic Press.

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

Pineño. O., Vegas, S., & Matute, H. (2003). Factores que median en la expresión del aprendizaje asociativo humano. In J. Vila, J. Nieto & J. M. Rosas, *Investigación contemporánea en aprendizaje asociativo* (En prensa).

Paredes-Olay, C. & Rosas, J. M. (1999). Within-subjects extinction and renewal in predictive judgments. *Psicológica*, *20*, 195-210.

Rosas, J. M., Vila, N. J., Lugo, M., & López, L. (2001). Combined effect of context change and retention interval upon interference in causality judgments. *Journal of Experimental Psychology: Animal Behavior Processes*, *27*, 153-164.

Spence, K. W. (1936). The nature of discrimination learning in animals. *Psychological Review*, *43*, 427-449.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review*, *64*, 49-60.

Vila, N. J. & Rosas, J. M. (2001a). Reinstatement of acquisition performance by presentation of the outcome after extinction in causality judgments. *Behavioural Processes*, *56*, 147-154.

Vila, N. J. & Rosas, J. M. (2001b). Renewal and spontaneous recovery after extinction in a causal learning task. *Mexican Journal of Behavior Analisis*, *27*, 79-96.