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Interference between cues requires a causal scenario: Favorable evidence for causal reasoning models in learning processes

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ABSTRACT

In an interference-between-cues design (IbC), the expression of a learned Cue A–Outcome 1 association has been shown to be impaired if another cue, B, is separately paired with the same outcome in a second learning phase. The present study examined whether IbC could be caused by associative mechanisms independent of causal reasoning processes. This was achieved by testing participants in two different learning situations. In the Causal Scenario condition, participants learned in a diagnostic situation in which a common cause (Outcome 1) caused two disjoint effects, namely Cues A and B. In the Non-Causal Scenario condition, the same IbC design and stimulus conditions were used. However, instructions provided no causal frame to make sense of how cues and outcomes were related. IbC was only found in the Causal Scenario condition. This result is consistent with Causal Reasoning Models of causal learning and raises important difficulties for associative explanations of IbC.

Generally, interference refers to a difficulty in the recall of information that has been stored at a given point in time due to the acquisition of some other information at a different time. Retroactive interference between cues of the same outcome (IbC hereafter) occurs when the behavioral expression of an association between a cue and an outcome (e.g., A → 1) is reduced due to the later acquisition of an association between a different cue and the same outcome (B → 1; see Table 1). The phenomenon has been obtained using trial-by-trial learning situations, typically employed in the study of human learning (see, for example, Escobar, Pineño, & Matute, 2002; Matute & Pineño, 1998; Ortega & Matute,

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Table 1
Experimental design

Experimental groups	Training phases		Test phase
	Phase 1	Phase 2	
	Context X	Context Y	Context Y
Non-Causal Scenario-Same outcome	Cue A → O1 Cue C→ O3	Cue B → O1 Cue C → O3	Cue A?
Non-Causal Scenario-Different outcome	Cue A → O1 Cue C → O3	Cue B → O2 Cue C → O3	Cue A?
Causal Scenario-Same outcome	Effect A → Cause O1 Effect C → Cause O3	Effect B → Cause O1 Effect C → Cause O3	Effect A?
Causal Scenario-Different outcome	Effect A → Cause O1 Effect C → Cause O3	Effect B → Cause O2 Effect C → Cause O3	Effect A?

Note. Letters A–C and numbers stand for cues and outcomes, respectively. Only in the Causal Scenario conditions do the cues represent effects of the outcomes. Letters X and Y stand for different contexts.

2000; Pineño, Ortega, & Matute, 2000) as well as animal learning (Escobar, Arcediano, & Miller, 2001; Escobar, Matute, & Miller, 2001; Escobar & Miller, 2003).

There are several reasons for this interest in the study of IbC. First, there is a significant resemblance with an analogue interference phenomenon studied in the memory field using paired associates tasks that attracted researchers from the 1940s through the 1960s (see Slamecka & Ceraso, 1960, for a review). Specifically, researchers in this field studied the effect of learning paired associates of the form C-B on the recall of previously learned paired associates of the form A-B. Some studies showed retroactive inhibition in the recall of the first learned list (Greenbloom & Kimble, 1965; Keppel, Bonge, Strand, & Parker, 1971, but see, for example, Petrich, 1970). Because of the similarities between the A-B, C-B designs used in paired associates studies and the IbC design (see Table 1) used by Pineño and Matute (2000), these authors have suggested that the inhibition effect obtained in both paradigms could be "integrated into a general framework of interference theories" (Pineño & Matute, 2000, p. 31). Secondly, there are formal similarities between IbC and the backward-blocking phenomenon studied in the associative learning literature. This phenomenon has focused the attention of numerous studies as a tool to discriminate between the predictions of different learning theories. As in IbC, in backward blocking, responses to a cue, A (that has been previously paired with an outcome), decrease due to a later training in which a different cue B is paired with the same outcome. The only difference is that in this case, previous training with cue A occurs in a compound stimulus with cue B. Thus, Escobar et al. (2002), based on this similarity, have tried to derive a common explanation for both phenomena and have also questioned traditional accounts of blocking. Thirdly, IbC has been related to interference between outcomes, a classic phenomenon in the learning literature (Pineño & Matute, 2000). In interference between outcomes, the same cue is paired with a specific outcome in Phase 1 of the learning session and with a different outcome in Phase 2. Recently, an adaptation of Bouton (1993) memory retrieval model, originally developed to account for the interference between outcomes effect, has been proposed to explain IbC. Thus, according to Pineño and Matute (2000) or Miller and Escobar (2002), IbC is the result of a failure to retrieve the first association (i.e., A-1) at test due to the activation of the association learned in the second phase (i.e., B-1); a very similar explanation to that proposed originally by Bouton as an account of the interference between outcomes phenomenon (see Bouton, 1993).

In addition, IbC has also served to study the implication of causal reasoning processes in the learning of relationships between events. According to Cobos, López, and Luque (2007), most of the evidence showing IbC in humans has come from experiments that have used learning tasks amenable to being interpreted in causal terms. These authors further argue that the events described in such tasks may be interpreted more naturally in a diagnostic rather than in a predictive sense (i.e., according to the instructions, participants are invited to interpret cues and outcomes as effects and causes, respectively). For example, in the spy-radio task, the most frequently and successfully used task to induce IbC (Escobar et al., 2002; Pineño & Matute, 2000, 2005; Pineño et al., 2000), participants have to rescue

as many refugees as possible in a war zone plagued with hidden mines by repeatedly pressing the space bar to place the refugees in a series of trucks. The colored lights of a spy radio, which play the role of cues, tell the state of the road (free of mines, mined, or closed) on each trial. In this case, the causal scenario is very likely to induce participants to interpret the colored lights of the spy radio as effects of the state of the road on some kind of detector device. After all, people are very familiar with the existence of mine detectors and devices that can detect metals or other sort of materials (see Cobos et al., 2007, for further justification). Based on causal reasoning models, such as Bayesian causal networks (e.g., Glymour, 2001) or causal model theory (e.g., Waldmann & Holyoak, 1992), Cobos et al. (2007) state that IbC may occur due to a diagnostic interpretation of the task. According to a diagnostic interpretation of an IbC design (see Table 1), Cause 1 produces Effect A during Phase 1 whereas in Phase 2 it stops producing this effect and starts producing a new effect, Effect B. According to the learners' prior causal knowledge, Cause 1–Effect A and Cause 1–Effect B relationships must be mutually exclusive because effects A and B never occur simultaneously. In other words, only one of the two causal relationships is present at any given time. This makes the context (either temporal or physical) of each learning phase causally relevant to solving the task, as it signals which of the two relationships is valid. Because the test phase takes place right after the last training trial of Phase 2, participants assume that the context has not changed, that is, the test also occurs in Phase 2. For the reasons described above, Phase 2 context has become a signal that Cause 1–Effect A is not the current valid relationship. Thus, when participants are presented with Cue (Effect) A at test, they are not sure of whether or not it has been produced by Cause 1. This doubt is reflected in a lower number of responses to cue A than in a control condition (the Different Outcome condition) in which Cues A and B are paired with different outcomes (i.e., an IbC effect is observed; see Table 1). Following this line of reasoning, IbC should not be observed in a predictive situation (i.e., participants interpret cues and outcomes as causes and effects, respectively; see Cobos et al., 2007 for a more detailed and formal justification of this).

Cobos et al.'s (2007) experiments showed evidence supporting this prediction. Specifically, it was shown that IbC only occurred when a diagnostic but not a predictive causal scenario was provided through instructions. However, these results do not rule out the existence of an associative-based IbC once the causal scenario is removed from the learning task. The instructions provided in all Cobos et al.'s experiments clearly framed the learning task in a causal scenario in which the causal role of cues and outcomes was explicitly specified. Thus, this may have made the causal reasoning processes override the associative mechanism and thereby produce the observed influence of causal order on IbC. Since the causal role of cues and outcomes is not as explicitly stated in other studies as in Cobos et al. (2007), it is not quite clear if the IbC observed in such studies is the outcome of causal reasoning processes or the result of by-default associative learning and memory mechanisms. In other words, Cobos et al.'s results leave open the question of whether the IbC effect necessarily needs the operation of causal reasoning processes or whether there exists an associative IbC due to a default associative mechanism operating in the absence of any explicit causal scenario.

To solve this question, the objective of the present study was to evaluate whether the observation of IbC necessarily requires a diagnostic causal scenario or, alternatively, whether it may be observed in the absence of any causal scenario. For this, an experiment was carried out aimed at evaluating IbC in two target conditions: a diagnostic causal condition and a non-causal condition (i.e., the instructions did not provide any causal interpretation for cues and outcomes). It is important to note that both conditions were identical regarding the stimuli used and, thus, any potential modulatory effect on the IbC should be attributed to the semantic interpretation of these stimuli. If purely associative-based memory retrieval processes are responsible for IbC, it should also be obtained in the non-causal condition. On the other hand, if IbC requires a diagnostic causal interpretation to occur, it should only be observed in the diagnostic causal condition. Additionally, the experiment was also aimed at overcoming a potential difficulty of Cobos et al.'s (2007) experiments, namely that the manipulation of causal order correlated with the use of different stimulus conditions. Previous findings in the paired-associates literature have shown that increasing the similarity between Cues A and B changes the results from interference to facilitation (see Slamecka & Ceraso, 1960). Thus, an alternative explanation to that based on causal reasoning processes could be invoked to account for Cobos et al.'s results. By keeping constant the stimulus conditions in the present experiment, any potential influence other than the semantic interpretation of cues and outcomes is cancelled out.

The objective of the experiment was then to assess the interaction between IbC and the presence (or absence) of a causal scenario. The participants were randomly assigned to a Causal Scenario condition or a Non-Causal Scenario condition. In both conditions, the learning task was identical except for the instructions participants could read. In the Causal Scenario condition, according to the instructions, the cues and the outcomes played the role of effects and causes, respectively; whereas in the Non-Causal Scenario condition, no causal connection was suggested and cues were only presented as being potentially predictive of the outcomes. Thus, the experiment evaluated IbC (see Table 1) in both, the Causal Scenario and the Non-Causal Scenario conditions. Consequently, a 2×2 between-groups design was adopted with a total of four conditions resulting from crossing the two levels of the Causal Scenario variable (Causal Scenario vs. Non-Causal Scenario) with the two levels of the IbC design (Same Outcome vs. Different Outcome): Causal Scenario-Different, Causal Scenario-Same, Non-Causal Scenario-Different and Non-Causal Scenario-Same.

If IbC necessarily requires a causal interpretation of the events, it should only be observed in the Causal Scenario group (i.e., the number of responses to A at test should be lower in Group Causal Scenario-Same than in Group Causal Scenario-Different). In that case, the associative interpretation given to the IbC obtained in similar experiments (e.g., Matute & Pineño, 1998; Pineño & Matute, 2000) would have some difficulties. Otherwise, IbC should be observed in both groups of the Causal Scenario variable.

Methods

Participants and apparatus

The participants were 134 undergraduate psychology students from the University of Málaga who took part in the present experiment for course credits. They were randomly assigned to one of the four experimental conditions. The task was performed on IBM-PC compatible computers in semi-isolated individual cubicles.

Procedure

Participants started by reading the instructions on the computer screen placed in one of the 10 cubicles in the laboratory. The instructions contained a detailed description of the experimental task described here (a translated version of the instructions can be found in Appendix A). The learning task in the Causal Scenario conditions was practically identical to the diagnostic group described in Cobos et al. (2007); Experiment 2. In this task, participants were invited to imagine that they were physicians working for the Red Cross organisation in a very poor area. Due to hunger, the inhabitants of certain towns had begun to eat plants, some of which were poisonous. On each trial, participants had to guess whether or not a hypothetical patient had eaten a poisonous plant and, if so, they had to administer a certain amount of antidote to prevent the poisoning symptoms. If the patient had eaten a poisonous plant, then participants could gain as many points as the number of antidote units administered. Such units could be administered by repeatedly pressing the space bar or by keeping it pressed for a fixed period of time. In addition, patients could have also eaten either an anomalous or an innocuous plant. Administering the antidote to a patient who had eaten the anomalous plant caused her/him to be intoxicated, and thus, participants lost as many points as antidote units had been administered. Eating the anomalous plant did not cause symptoms provided that the antidote had not been administered. Finally, the administration of the antidote had no effect on those patients that had eaten the innocuous plant, and thus, participants did not gain or lose points on these trials regardless of the amount of antidote administrated. The instructions encouraged participants to gain as many points as possible by the administration of antidote in trials in which the patient had eaten the poisonous plant and avoiding its administration in trials in which the patient had eaten the anomalous plant.

According to the Causal Scenario instructions, the ingestion of each type of plant could be recognized by the alteration of one of three possible chemical reagents of different colours: brown, yellow, or blue. Thus, each trial provided information about the only reagent altered for a hypothetical patient, and participants had to learn the relationship between each altered reagent and the ingestion of each

type of plant. The chemical reagents served as cues from which to infer the plant eaten by each patient. Thus, the different chemical reagents and the different plants eaten by the patients played the role of cues and outcomes displayed in Table 1, respectively. Note that the alteration of the different reagents were effects from which the different causes (the different plants eaten) could be diagnosed, i.e., it was a diagnostic task.[1] Participants had to decide on each trial, the amount of antidote that had to be administered from knowing the specific reagent that was altered. After responding, participants received corrective feedback.

Table 1 shows the different relationships that were programmed to evaluate IbC for all conditions. Specifically, according to the Causal Scenario instructions, in the Same outcome condition, cues A and B indicated that the patient had eaten the same poisonous plant, i.e., Plant 1 (O1 in Table 1); whereas Cue C indicated that the patient had eaten an anomalous plant, i.e., Plant 3 (O3 in Table 1). The only difference with the Different outcome condition is that in the latter case, Cue B indicated that the patient had eaten an innocuous plant, Plant 2 (O2 in Table 1). As Cue A indicated the ingestion of the poisonous plant and Cue C indicated the ingestion of the anomalous plant, a good performance would involve a high response rate (i.e., a high number of antidote units administered) in the presence of Cue A and a low response rate (i.e., a small number of antidote units administered) in the presence of Cue C. During the test phase, responses to Cue A were required, and an IbC effect would be observed if a lower rate of responding was obtained in the Same Outcome at test than in the Different Outcome condition. Note that the response rate to A represents an indirect measure of the extent to which participants expect Outcome 1, i.e., the ingestion of the poisonous plant.

Once participants had read the instructions and all questions were answered, the experimental task started with a two-stage training phase and a test phase. In each training phase, participants were presented with hypothetical patients from one of two different groups of people: "ULUS" and "GANTUAS". These groups played the role of Contexts X and Y displayed in Table 1. The assignment of these roles to each group of people (ULUS or GANTUAS) was counterbalanced across participants. For all conditions, during Phase 1, all participants were exposed to 10 A-1 trials intermixed with 10 C-3 trials. Then, participants in the Same outcome condition received 10 B-1 trials intermixed with 10 C-3 trials during Phase 2, whereas participants in the Different outcome condition received 10 B-2 trials intermixed with 10 C-3 trials during Phase 2. The order of trials was randomized, with the constraint that no more than two consecutive presentations of the same trial type were allowed. Participants were not told about the test trial, which consisted of an additional A-1 trial after the last trial of Phase 2. The context for the test trial was the same as for Phase 2, Context Y. In the Causal Scenario condition, cues A through C were assigned to the different reagents according to a counterbalancing procedure. Outcomes 1, 2 and 3 were the poisonous, the innocuous, and the anomalous plant, respectively. In order to increase the discriminability among the different outcomes, each of the three different plants was assigned a photo and a fictitious name, "Dobe", "Yamma", and "Kollin". A counterbalancing procedure was adopted for this assignment.

On each trial of the Causal Scenario condition, the message "In the case of Patient #, the unique reagent altered was:" appeared at the top centre of the screen. Just below, a small rectangle filled with the corresponding color was displayed (see Fig. 1 for details concerning the actual information displayed on each trial). The color (i.e., the cue) appeared only for 3.5 s. After that time, the rectangle became blank (i.e., grey as the background color). Participants could administer the antidote by pressing the space bar while the color of the reagent altered was visible (i.e., in the presence of the cue). After the color disappeared, pressing the space bar ceased to have an effect on the amount of antidote given. A scrollbar at the bottom center of the screen indicated the amount of antidote that was being administered. If the spacebar was held pressed, the scrollbar face moved smoothly from left to right. The position of the face was translated into a number of antidote units from 1 through 100 displayed in a small textbox on the right of the scrollbar. The initial position of the face on each trial was the left extreme of the scrollbar, which corresponded to zero antidote units (see Fig. 1). Once the 3.5 s for the cue presentation had elapsed, participants received information about the outcome. The outcome included

[1] Cobos et al. (2007) also designed a predictive version with the same causal scenario. In this condition, plants (causes) were cues from which to predict the alteration of the chemical reagents (effects).

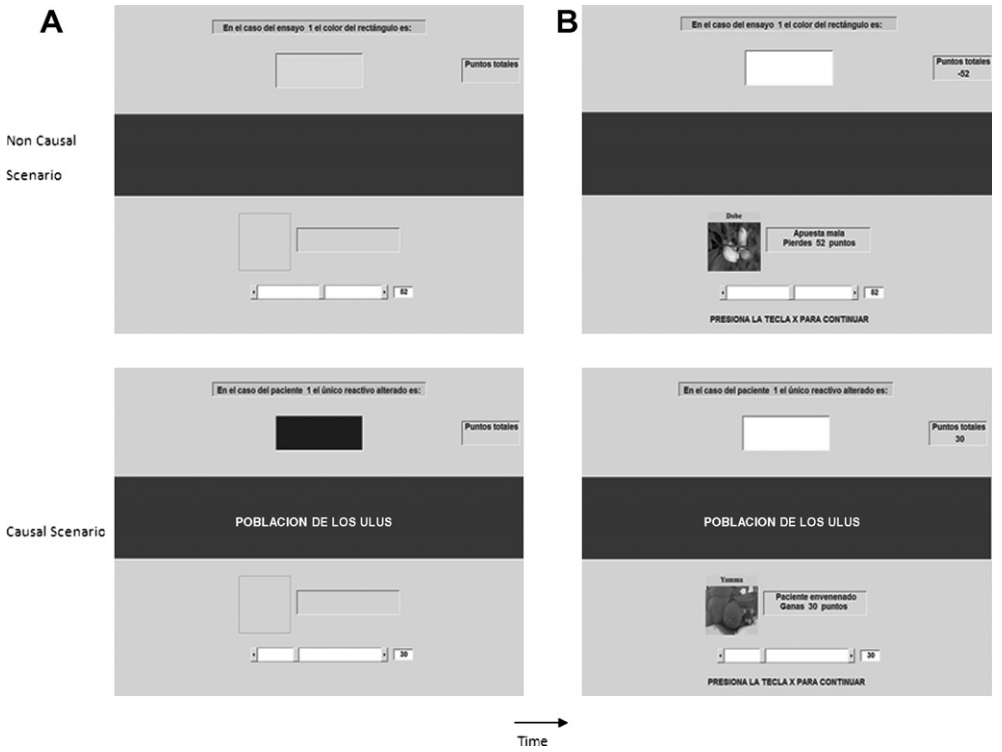

Fig. 1. Information displayed on a training trial in the different Causal Scenario conditions, as seen during the actual task. (A) *Cue presentation.* The grey shaded rectangle at the top of the screen represents the cue presented on the actual trial. Participants could only respond during the 3.5 s. interval when the rectangle stayed colored (i.e., cue present). A scrollbar at the bottom center of the screen indicated the number of responses given (see main text). After this period of time, the outcome screen was automatically presented. (B) *Outcome presentation.* The photo of the plant, its name and the number of points gained or lost were presented immediately after the cue had disappeared. The big rectangle at the centre of the screen represented the context (see main text). Participants had to press the "X" key to continue with the next trial.

a photo of the plant and its name. In addition, a message indicating the state of the patient, and the number of points won or lost was displayed in a small textbox just above the scrollbar. If the hypothetical patient was poisoned, the message displayed was "poisoned patient; you win # points"; if the patient had eaten the anomalous plant, the message was "sensitised patient; you lose # points"; if the patient had eaten the innocuous plant, the message was "healthy patient; you neither win nor lose points" (see Fig. 1). The points referred to in the message were the number of antidote units given by the participant. These points were added or subtracted to the accumulated points displayed in a small textbox located at the top right of the screen, at the same height as the reagent's color. The outcome information remained on the screen until participants pressed the 'X' on the keyboard. Then all the outcome information was removed except the accumulated points, and the next trial followed 2 s later. Throughout the task, information about the context was displayed in a big rectangle as wide as the screen width at the centre of the screen. The message "ULUS (or GANTUAS) PEOPLE" appeared in big size letters within the rectangle. The rectangle was either red or green, depending on the training phase. The assignment of each color to each phase was counterbalanced across participants. The context was displayed as a constant background that remained unchanged throughout the entire training phase (see Fig. 1).

The learning task in the Non-Causal Scenario conditions was as in the Causal Scenario conditions except that the instructions did not mention any detail concerning the causal cover story or the causal interpretations of cues and outcomes (see Appendix A). Thus, procedural details such as the stimuli

presented as cues and outcomes, the display of the information on the screen, and the timing of this information were identical. Some differences were introduced, though, to specifically avoid any reference to a causal scenario.

For example, the instructions, rather than focusing on the administration of antidote units, stated that participants had to bet in order to gain as many points as possible. These points could be bet on each trial by pressing the space bar. Participants were informed that betting points could have three consequences depending on the cue present on a given trial: (a) gaining points (if the space bar was pressed in the presence of one particular cue or, in the Group Same, one or more cues); (b) losing points (if the space bar was pressed in the presence of another cue); (c) and neither gaining nor losing points (if the bar was pressed in the presence of another cue, though only for Group Different; see Table 1). The participants were informed that cues were the different colors of a rectangle (the same rectangle that played the role of chemical reagents in the Causal Scenario condition), though now, no further semantic interpretation was attributed to them beyond serving as signals for the consequences of betting points (see the instructions in Appendix A). Different plant photos were displayed as part of the feedback. Participants were told that there was a "good plant", a "bad plant" and a "neutral plant", and that points could have been gained, lost or neither, respectively, depending on the specific plant present as part of the outcome. Participants were invited to learn the associations between the color cues and the plants to help them to make good bets. In the Non-Causal Scenario conditions, the same big-colored rectangle appeared in the center of the screen, but no reference to any population was made (i.e., ULUS or GANTUAS). Note that these instructions allowed us to display the same stimuli (cues, outcomes and contexts) as in the Causal Scenario condition, but without any reference to causal links between them.

The text displayed on top of the screen throughout the learning task was slightly changed in order to remove all references to a causal scenario. The message "In the case of Patient #, the unique reagent altered was" was replaced by "In the case of trial #, the color of the rectangle is". The messages that formed part of the outcome, such as "poisoned patient", "sensitized patient", and "healthy patient", were replaced by the new messages "good bet", "bad bet", and "neutral bet", respectively (see Fig. 1).

Results

To ensure that the analysis excluded the data from those participants who did not pay a minimal level of attention to the task, only the data from those participants who met a certain learning criterion were selected for further analysis. Specifically, participants were selected if the total score (i.e., the number of points gained during the learning phases) was higher than 0. As a result, 125 participants from the initial sample were selected for data analysis: 29 from the Causal Scenario-Different condition, 32 from the Causal Scenario-Same condition, 31 from the Non-Causal Scenario-Different condition and 33 from the Non-Causal Scenario-Same condition. Fig. 2 displays the mean response rate for each condition in the test phase and shows a greater IbC effect in the Causal Scenario than in the Non-Causal Scenario condition. This impression was confirmed by a 2 (IbC: Same Outcome vs. Different Outcome) $\times$ 2 (Causal Scenario: Causal Scenario vs. Non-Causal Scenario) ANOVA. The ANOVA showed a significant effect of IbC, $F(1,121) = 13.02$, $p < .001$, $p_{rep} = .99$, $\eta 2 = 0.1$, a significant effect of Causal Scenario, $F(1,121) = 12.51$, $p < .001$, $p_{rep} = .99$, $\eta 2 = 0.09$, and a significant interaction between both factors, $F(1,121) = 5.85$, $p < .02$, $p_{rep} = .93$, $\eta 2 = 0.05$. A more detailed analysis showed that the IbC effect was significant in the Causal Scenario condition, $F(1,121) = 13.11$, $p < .001$, $p_{rep} = .99$, $\eta 2 = 0.18$, but not in the Non-Causal Scenario condition $F(1,121) = 1.09$. The highly significant effect of IbC in the Causal Scenario condition and its absence in the Non-Causal Scenario condition explain the Causal Scenario, IbC, and their interaction effects. Thus, the results show that, even if the stimulus conditions are held constant, IbC is only observed when participants are provided with a causal scenario which invites them to interpret cues and outcomes in terms of effects and causes. In the absence of any causal scenario, IbC is no longer observed. Additionally, as can be seen in Fig. 2, responses in the Causal Scenario-Different group were almost the same as in the Non-Causal Scenario-Different group, whereas a marked difference was found between the Causal Scenario-Same and the Non-Causal Scenario-Same group. This was confirmed by the analysis of the simple effects of

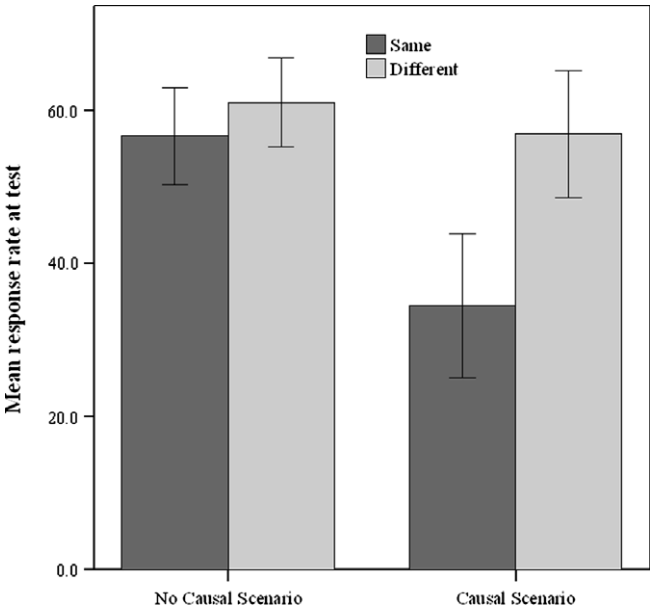

Fig. 2. Mean response rate for each condition during the test phase. Response rate represents the amount of antidote administrated on each trial by pressing the space bar while the cue was present (3.5 s). Error bars represent 95% confidence interval.

Causal Scenario. The effect of Causal Scenario was significant in Group Same, $F(1,63) = 16.06$, $p < .001$, $p_{rep} = .98$, $\eta 2 = 0.2$, but not in Group Different $F(1,58) < 1$. This specific pattern of results strongly supports the causal reasoning-based explanation of how the causal interpretation of cues and outcomes should affect the observation of IbC.

In addition to the analysis reported above, participants' responses at the end of the learning phase were analysed to be sure that the differences found at test were not due to differences in learning to discriminate between the different cues during the first and the second learning phase. One could argue that the different scenarios conveyed by the instructions could have had an influence on learning due to reasons other than to the Causal–Non-Causal dimension (e.g., scenarios could have different motivational properties). Fig. 3 displays the mean responses in each trial for cue A (i.e., Phase 1) and cue B (i.e., Phase 2) in all conditions. For simplicity, the analysis was only focused on the Same-outcome groups as no significant difference was found at test between the Causal Scenario-Different and the Non-Causal Scenario-Different groups. Two different analyses, one per learning phase, were performed on participants' responses averaged over the last three trials of each trial type. For responses in the first learning phase, a 2 (Cues: Cue A vs. Cue C) $\times$ 2 (Causal Scenario: Causal Scenario vs. Non-Causal Scenario) ANOVA with a within-subjects and a between-subjects factor yielded a significant effect of Cues, $F(1,63) = 886.85$, $p < .001$, $p_{rep} = .99$, $\eta 2 = 0.93$. No further effects were significant (all F's < 1). The mean responses for Cue A were 67.02 and 68.05 in the Causal Scenario and Non-Causal Scenario groups, respectively; for Cue C, the mean responses were 0.26 and 1.88 in the Causal Scenario and Non-Causal Scenario groups, respectively. This result shows that both the Causal Scenario and the Non-Causal Scenario groups acquired good discrimination performance at the end of Phase 1, as the response rates were high for Cue A and almost zero for Cue C. Furthermore, these groups did not differ from each other, as no effect involving the causal scenario factor was found. For responses in the second learning phase, the same ANOVA was performed, except for the fact that factor Cues now involved levels B and C. Again, the only significant effect of found was for the factor Cues, $F(1,63) = 1776$, $p < .001$, $p_{rep} = .99$, $\eta 2 = 0.97$ (all the remaining Fs < 1). The mean responses for Cue B were 69.36 and 69.24 in the Causal Scenario and Non-Causal Scenario groups, respectively; for Cue C, the response means were 0.23 and 0.47 in the Causal Scenario and Non-Causal Scenario

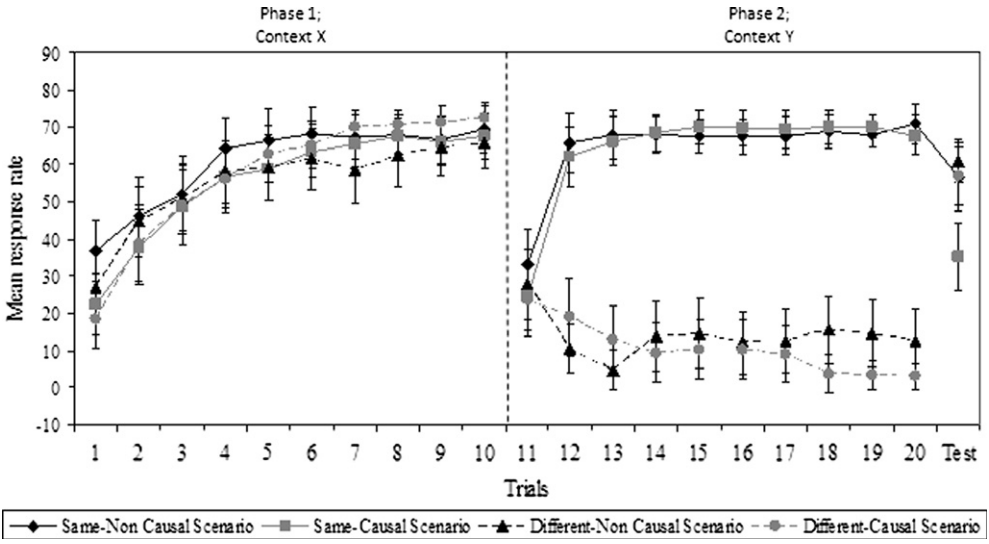

Fig. 3. Mean response rate curves for Cue A (i.e., Phase 1) and Cue B (i.e., Phase 2; see Table 1) throughout training trials. Error bars represent 95% confidence interval.

groups, respectively. Thus, both groups reached a good level of discrimination performance at the end of Phase 2, and no difference was found between them. As a consequence, the different IbC effect found in the Causal Scenario and Non-Causal Scenario groups cannot be attributed to differences in the participants' discrimination performance during both learning phases.

Discussion

Cobos et al. (2007) showed that IbC can be modulated by causal reasoning processes in a study in which IbC was only observed when the learning task was framed within a diagnostic causal scenario, but not when the learning task was framed within a predictive causal scenario. However, Cobos et al. (2007) did not show whether IbC can be observed in the absence of any causal scenario, as would be expected according to the associative accounts of IbC that have been put forward so far (Miller & Escobar, 2002; Pineño & Matute, 2000). In the present study, the instructions were manipulated to assess whether IbC requires a causal interpretation of the task or, alternatively, whether it can be observed even when no causal scenario is provided to understand how cues and outcomes are related. The present results support the idea that IbC requires a causal scenario. Specifically, IbC was observed when, according to the instructions, cues and outcomes played the roles of effects and causes, respectively. However, this effect was no longer observed when the instructions did not provide any causal frame to make sense of the relationships between cues and outcomes. In other words, the operation of causal reasoning processes appears to be necessary for obtaining IbC.

The results reported here are consistent with Cobos et al.'s (2007) results, as the former provide convergent evidence that the IbC effect depends on the causal interpretation of the learning task. This evidence is especially compelling here as the manipulation of the instructions kept the stimulus conditions practically unchanged. Thus, these results, as well as Cobos et al.'s, give strong support to a causal-reasoning-based account of IbC and raise important difficulties for associative accounts of IbC, as the latter cannot explain how the semantics of cues and outcomes modulates the observation of this phenomenon even when the stimulus conditions are held unaltered.

However, this pattern of results goes a step forward in assessing the existence of an IbC effect with a pure associative basis in human contingency learning paradigms. All previous attempts to show IbC in these paradigms have used learning tasks in which cues and outcomes were more or less explicitly

causally connected, or at least, learning tasks for which the instructions provided participants with a causal interpretation of cues and outcomes. Thus, in the light of the results reported here, there are doubts concerning the extent to which the IbC reported in those experiments was the genuine product of the operation of associative storage and retrieval processes, as it was originally interpreted. In this sense, it seems sensible, if not necessary, to design learning tasks with no causal frame favoring a causal interpretation of cues and outcomes as a means to provide a rigorous test for the implication of associative processes in the production of an IbC effect. Strictly speaking, causal cover stories aimed to induce a causal interpretation of the learning task are not necessary for associative processes to operate. As far as we know, the experiment reported here, at least in the Non-Causal Scenario condition, is the first experiment, within the human contingency learning field, which has tried to find an IbC effect while explicitly avoiding the use of a causal scenario. Thus, to the extent that no IbC effect was found in this condition, the study casts doubts on the existence of a genuinely associative IbC effect in this literature.

There are, however, empirical demonstrations of IbC outside the field of human contingency learning (see e.g., the paired associates literature, Keppel et al., 1971; and, more recently, in animal conditioning preparations, e.g., Escobar et al., 2001) in which it would simply be unreasonable to invoke the operation of causal reasoning processes. Thus, all in all, there may be several ways in which the so called IbC can occur. In other words, these demonstrations of IbC may be different psychological phenomena under an identical name. And in these other fields, associative processes may play a significant role in the explanation of the phenomenon. However, and more importantly, in terms of the evidence found, it is causal reasoning theories that seem to provide a more robust explanation of the specific IbC effect found in human contingency learning. Thus, the evidence reported here and that of Cobos et al. (2007) show the limitations of the integrative approach proposed by Escobar et al. (2001), according to which the IbC found in the animal conditioning, paired associates, and human contingency literatures could be encompassed within a common associative explanation.

In sum, this pattern of results contributes to the evidence supporting causal reasoning theories in other areas of human contingency learning phenomena, such as blocking (Booth & Buehner, 2007; De Houwer, Beckers, & Glautier, 2002; Waldmann & Holyoak, 1992) and overshadowing (López, Cobos, & Caño, 2005; Waldmann, 2000, 2001). Interestingly, whereas these studies show that blocking and overshadowing tend to disappear in causal diagnostic situations, the present study, together with Cobos et al. (2007), shows that IbC is only observed in such situations. It is this differential effect of diagnostic situations on these learning phenomena that is specifically predicted by causal reasoning theories.

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Appendix A

Set of instructions used in the experiment, translated from Spanish. Specific instructions for the Different Outcome conditions are included between box brackets.

Causal Scenario conditions

Imagine the following situation.

You are a doctor working for the Red Cross in a poor area in a third world country where you are in charge of the health of several groups of people. The inhabitants of the area, due to famine, are eating plants that they are not used to. One of these plants is poisonous as various intoxications have already

been produced in those who have eaten it. Your main objective is to slow down this intoxication by finding out which plant is poisonous and administering an antidote when necessary.

Your task would be easy if it was not for several difficulties. First, the symptoms from the poisoning do not appear immediately, but when they do appear they do so suddenly, giving no time for the administration of the antidote. Moreover, the antidote may poison the patient when administered after eating one of these plants: the "anomalous plant". Thus, you will have to find out if your patients have eaten this plant so that you will not administer any antidote.

Then, how can this administration be done? Well, if you think that the patient has eaten the poisonous plant, you should administer the antidote. If you think that they have eaten the "anomalous plant", you should not administer the antidote at all. [Different outcome condition: If you think that a so-called "healthy plant" has been eaten, it does not matter whether you administer the antidote, as this plant is harmless].

Fortunately, though the symptoms from the intoxication are slow to appear, the consumption of the different plants produces an immediate reaction: color changes in different chemical reagents. Thus, you may find out the plant eaten from knowing which reagent has been altered. Hence, it is important that you should learn the relationships between the different plants eaten and the consequent changes in the reagents, in order to save the greatest number of people.

During the task, you will observe which reagent is altered for each patient. It is important to note that for each patient, only one reagent is altered. According to the reagent altered, you will have to decide whether to administer the antidote to the patient or not. For this, you will have to press the space-bar on the keyboard and you will be able to check the amount of antidote that is being administered on the screen. The more you press the space-bar, the more antidote will be administered; for a quicker administration of the antidote, you may keep the space-bar pressed. Due to the number of patients that you will have to examine, the time allotted to each of them is limited: you will only be able to administer the antidote while the reagent remains visible on the screen.

To check how well you are doing the task, you will get points for your actions. Once you have decided to administer (or not) the antidote, you will see the plant that the patient had eaten and whether this was "poisonous", "anomalous" [Different outcome condition: or "healthy"]. If the antidote is administered after the patient had eaten the "poisonous" plant, you will get as many points as the amount of antidote you had administered (for example, if you give 100 units of antidote and the patient had eaten the "poisonous" plant, you will get 100 points, which it is not bad at all!). However, if the antidote is administered to a patient that had eaten the "anomalous" plant, you will lose as many points as the units of antidote you administered (for example, if you give 100 units of antidote and the patient had eaten the "anomalous" plant, you will lose 100 points, you have poisoned your patient!). [Different outcome condition: Finally, if the patient had eaten the "healthy" plant, you will not get or lose points as the antidote does not affect the patient at all.]

In each trial, you will see the following information. In the top central part of the screen, the reagent will appear, initially, in grey color. You will be able to administer the antidote while the reagent is altered (only a few seconds) by pressing the space-bar. Afterwards, you will learn the plant eaten ("poisonous", "anomalous" [Different outcome condition: or "healthy"]), the number of points gotten or lost and the state of the patient. You will see the number of points accumulated in the right top section of the screen. To see the reagent altered in the next patient you will have to press "X" on the keyboard.

A piece of advice: if you keep your left-hand index finger on the "X" key and the right-hand index finger on the space-bar, you will not have to search for the keys while examining the patients.

Once you have finished examining patients from a population, you will continue your humanitarian task in the next population. This change in the population examined will be clearly marked on the screen.

REMEMBER: Your objective is to learn the relationship between the reagents altered and the plants that produced these alterations in order to administer the antidote correctly and, thus, get the greatest number of points available.

If you have any doubt, please ask the experimenter!

Non-Causal Scenario conditions

In the task you are about to start, your objective is trying to get as many points as possible. Throughout these instructions, you will be told what the task is about. Read them carefully so that you can get many points.

The task is divided into a series of temporal intervals or trials in which you can get or lose points. To get points in a given trial, you only have to press the space-bar repeatedly or to keep it pressed for a while. Every time you press the space-bar during a trial, you bet a number of points that increases rapidly if you keep the space-bar pressed. In fact, you may get as many points as the time available allows you to bet.

Throughout trials, you may accumulate points that can be checked on every trial. However, the space-bar is not always operative. Moreover, in some trials, the points you bet may be lost and, thus, they will be subtracted from the total amount accumulated. [Different outcome condition: On other occasions, bet points are neither lost nor gotten.] Thus, in every trial, it must be decided whether to press the space-bar to bet or whether it is more convenient not to bet so that points gotten from previous trials are not lost.

In order to help you make your decision, there will be a series of elements on the screen. At the top of the screen, you will see a small rectangle that changes color. If the rectangle is grey colored, the space-bar is not operative; that is, no matter how hard you try to press it, no points may be gotten or lost. At some point, however, you will see that the rectangle changes its color and, after a few seconds, its color changes back to grey again. The space-bar is only operative when the rectangle is not grey colored. The rectangle may change to various colors.

One or more of these colors indicate that if the space-bar is pressed, you will get as many points as you are able to bet in the trial; another color indicates that if the space-bar is pressed, you will lose as many points as bet in the trial; [Different outcome condition: finally, another color indicates that if the bar is pressed, you will not get or lose any points]. Throughout the trials, you will have to discover what each of the colors indicates from its consequences.

You will be informed at the end of every trial about what these consequences are at the bottom of the screen, but you cannot press the space-bar any more. A message will tell you the number of points you have gotten or lost in that particular trial. In addition to this information, you will see a picture depicting a plant and its name. There are two [Different outcome conditions: three] different plants: a "good" plant which indicates that if you had pressed the space-bar in its presence on that particular trial, you would have gotten points (that is, you would have made a good bet); a "bad" plant which indicates that if you had pressed the space-bar, you would have lost points (that is, you would have made a bad bet); [Different outcome condition: finally, a "neutral" plant which indicates that if you had pressed the space-bar, you would have neither gotten nor lost points (you made a neutral bet)].

To sum up, throughout trials you will see that changes in the colors of the rectangle that appears at the top of the screen are followed by different types of plants at the bottom of the screen. You may bet as soon as the color of the rectangle is present and learn which colors predict each different plant so that you can bet only when you think that the'good' plant will appear.

A piece of advice. If you keep your left-hand index finger on the "X" key and the right-hand index finger on the space-bar, you will not have to search for the keys whenever you want to press them in each trial. In the center part of the screen, you will see a colored band. You do not need to worry if you notice that it changes its color, as this is what it will do after a certain number of trials.

Remember. Your objective is to learn the relationship between the different colors and the plant pictures so that you can correctly bet and, consequently, get the greatest number of points available.

If you have any doubt, please ask the experimenter!

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