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Interference Between Outcomes, Spontaneous Recovery, and Context Effects as Measured by a Cued Response Reaction Time Task: Evidence for Associative Retrieval Models

Estrella González-Martín, Pedro L. Cobos, Joaquín Morís, and Francisco J. López
University of Málaga

The most common associative explanation of interference is based on a retrieval failure. Retrieval, in turn, is considered as the result of an associative activation mechanism that is thought to be fast and automatic. However, up-to-date, there is no evidence of interference based on dependent measures specifically related to this kind of low level processes. The objective of the present study was to test whether interference phenomena can be observed by using a cued response task designed to detect low level retrieval processes. Experiment 1 evaluated whether the cued response task served to show a priming effect. Such effect allowed us to interpret the results found in the remaining experiments of the series. Experiment 2 aimed to find the interference effect by using the cued response task. Experiments 3 and 4 were conducted to assess whether spontaneous recovery and context-change effects could also be observed. The results showed that interference and recovery from interference phenomena can be attributable to fast retrieval processes, which is consistent with associative accounts of interference.

Keywords: interference, associative learning, automatic retrieval, context effects, spontaneous recovery

Retroactive interference between outcomes (hereafter interference) refers to a decrement in the expression of a learned relationship between events as a result of the later acquisition of another relationship. Specifically, this phenomenon is observed when learners are repeatedly presented with trials in which a certain cue, A, is followed by an outcome, 1, and, later on, they are presented with trials in which the same cue is followed by another outcome (say Outcome 2 or the absence of Outcome 1). In such cases, when participants are probed with Cue A at test, they make fewer responses denoting the expectation of Outcome 1 compared with a control condition in which the predictive value of Cue A does not undergo any change at all. The most widely accepted explanation of interference comes from research on learning in nonhuman animals and is based on associative mechanisms of learning and retrieval (Bouton, 1993; Nelson, Sanjuan, Vadillo-Ruiz, Pérez & León, 2011; Rosas & Callejas-Aguilera, 2006). According to the associative account, an association between the representation of a cue and the representation of an outcome is formed as a consequence of repeated cue–outcome pairings. The strengthened association allows for the retrieval of the outcome from the presence of the cue. Retrieval, in turn, is thought to be the result of a rapid and automatic associative activation process involving the representations of the cue and the outcome. The cues are said to activate the representation of the outcome in participants' memory. As we will see below with more detail, interference is explained as a retrieval failure in which the activation of the representation of the cue is no longer able to cause the necessary increment in the activation of the representation of the outcome. Correspondingly, the attenuation of interference is explained as a recovery from the failure of the associative activation process.

Despite the reliance of the associative account on fast retrieval processes, most of the experiments conducted to provide evidence supporting the associative explanation have relied on the use of verbal judgments as a dependent measure (though see Matute, Lipp, Vadillo, & Humphrey, 2011), which allows for the engagement of slow processes based on inferential reasoning. The objective of the present study was to gather evidence of relevant interference phenomena using a cued response reaction time (RT) task that allows participants very little time to engage in reasoning process compared with traditional verbal judgments. Such evidence would provide strong support for the associative account of interference and might allow for a more direct comparison between interference in human and nonhuman animals.

A very relevant feature of interference is the evidence showing that it is not attributable to mere unlearning of the interfered relationship. For example, spontaneous recovery and some contextual effects show that the interfered relationship (A-1) is not completely deleted from memory by the trials of the subsequent interfering training phase (i.e., A-2 trials). Spontaneous recovery, which has also been found in animals (e.g., Bouton & Peck, 1992), is observed when the interference effect is partially or completely attenuated because of the insertion of a time-delay between the end

Estrella González-Martín, Pedro L. Cobos, Joaquín Morís, and Francisco J. López, Departamento de Psicología Básica, University of Málaga, Málaga, Spain.

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Correspondence concerning this article should be addressed to Estrella González-Martín, Departamento de Psicología Básica, Facultad de Psicología, Universidad de Málaga, Campus de Teatinos, s/n (29072), Málaga, Spain. E-mail: iviri_yo@hotmail.com

of the second training phase and test (see, e.g., Rosas, Vila, Lugo, & López, 2001, for evidence in humans). Contextual effects, which have been previously found in animals (Bouton & King, 1983; Brooks & Bouton, 1994; Bouton & Bolles, 1979), consist in the recovery of the expression of the relationship learned in the first place because of a contextual change from the interfering training phase to the test phase (see also Rosas et al., 2001, for evidence of context effects in humans).

Among the associative theories that explain interference, Bouton's (1993) theory is probably the most widely accepted in the field.[1] According to Bouton's theory, which comes from animal conditioning, the repeated exposure to conditional stimulus (CS)–unconditional stimulus (US)1 pairings lead to the formation of a permanent association between the representation of the CS and the representation of the US1 that allows for future retrieval of the latter from the presence of the former. Retrieval, in turn, is the result of the activation of the representation of the US1 resulting from the activation of the CS representation through the association previously formed. Later pairings between the same CS and another US (US2) make the CS become an ambiguous signal in the sense that it predicts the occurrence of two mutually exclusive outcomes. These new trials would entail the formation of an inhibitory association between the representations of the CS and the first US as well as an excitatory association between the CS and US2. To solve the conflict between the two relationships learned, the context of the relationship learned in the second place is coded so that both the inhibitory and the excitatory associations learned in the second place become context-dependent. Such context works as an and-gate that conditions the functionality of the associations learned in the second place. Thus, for the CS to activate the representation of US2, the context of the CS–US2 pairings must be present. Likewise, the inhibitory CS-US1 association also requires the presence of the context to produce its inhibitory effect. Thus, interference only occurs if participants are tested in the context of the interfering relationship. This is because such context would enable both the inhibition of US1 as well as the activation of US2. Alternatively, if the test phase takes place in a context different from that of the interfering relationship, interference tends to disappear because neither the inhibitory CS–US1 association nor the excitatory CS–US2 association will be effective. In turn, the activation of US1 from the CS representation will occur as this CS–US1 association is not context dependent. All forms of recovery from interference are explained on the basis of a context change from the interfering training phase to the test phase. This is clearly the case for all of the recovery effects attributable to contextual changes. But such explanation applies equally to spontaneous recovery as long as the time window in which training takes place is also considered as a context. According to this assumption, spontaneous recovery occurs because the delay time inserted between the interfering training phase and the test phase makes the temporal context of the latter differ from the temporal context of the former.

Bouton's theory of interference could also be understood in terms of response rather than retrieval interference. Thus, after learning the CS–US2 relationship during the second phase, both the representation of US1 and of US2 would be activated by the presence of the CS at test. As a consequence, the response elicited by US2 would interfere with that elicited by US1, thereby producing a decrease in the latter. However, if the individual is probed with the CS in a different context than that of the CS–US2 training, the interference would tend to disappear because of the context dependence of the relationship learned in the second place.

The main consequence from Bouton's (1993) theory for our purposes here is that interference is not attributable to unlearning but to a retrieval failure (or response interference) that can be prevented by changing the temporal or physical context from the second training phase to the test phase. The mechanisms responsible for interference and retrieval are thought to be fast processes of an associative nature.

Despite the central role of fast associative retrieval processes in the explanation of interference phenomena, to our knowledge, no evidence has been reported based on dependent measures that allow little room to the operation of slow reflective reasoning processes. The dependent measures used in most of the experiments conducted so far are based on participants' judgments about the relationships between cues and outcomes. When results based on verbal judgments results are taken as supporting an associative account of learning is because it is assumed that judgments somehow reflect the amount of associative activation of outcome representations. That is, a judgment about the extent to which a cue causes an outcome is related to the extent to which the cue triggers the associative retrieval of the outcome. However, there are several reasons to think that this assumption may not always be met. One of them is that participants have plenty of time to respond to verbal test questions, which opens up ample opportunities for the influence of inferential reasoning processes on participants' performance. Thus, in some cases, interference might be caused by reasoning processes rather than by a retrieval failure. For example, if participants learn that Medicine A causes Symptom 1 and Symptom 2 during the first and the second training phase, respectively, they could infer that Medicine A does not cause Symptom 1 any longer as A has been more recently followed by 2 rather than by 1; hence, the low causal ratings given to the A-1 relationship. Note that this is very different from saying that participants do not successfully retrieve the first outcome because little activation of its representation occurs. A study conducted by Scully and Mitchell (2008) provides interesting evidence consistent with this account of interference. They followed an acquisition/extinction procedure in which each of a series of cues was paired with a different outcome during the first training phase. Half of the cues underwent an extinction treatment later on, whereas the other half served as controls. As a result, participants' causal ratings about the extinguished relationships were much lower than for the control relationships, which would normally be interpreted as an interference effect. However, when participants were asked to recall the specific outcome that had been paired with each cue, interference was significantly reduced. Given this, there is no way to know to what extent the interference observed in causal judgments could be genuinely attributed to an associative retrieval failure.

[1] Having said that, it is interesting to notice that, recently, retroactive interference between outcomes has been related to retrieval-induced forgetting (Vadillo, Orgaz, Luque, Cobos, López, & Matute, in press). Thus, the same explanations of RIF based on inhibitory mechanisms to protect retrieval from interference could also be applied to interference between outcomes. However, further research is needed to reveal the precise role of RIF-like mechanisms in interference between outcomes.

Another reason for having doubts about the associative mediation in verbal judgments is that there is evidence that different ways of prompting participants' verbal responses lead to different results, which is difficult to reconcile with the exclusive operation of associative activation processes. Different patterns of results have been obtained depending on whether the test question was referred to the predictive value of the cue ("to what extent does Cue A predict the outcome"), to simple cue-outcome contiguity ("given that Cue A has occurred, to what extent the outcome has also occurred"; Matute, Arcediano, & Miller, 1996; though see Cobos, Caño, López, Luque & Almaraz, 2000), to the causal value of the cue ("to what extent does cue A cause the outcome"; Vadillo & Matute, 2007), to "preparatory" judgments (closely related to cue-outcome contiguity judgments; De Houwer, Vandorpe, & Beckers, 2007), or to counterfactual judgments ("in a situation in which the outcome would not occur in the absence of Cue A, how likely would the outcome be if Cue A were introduced?"; Collins & Shanks, 2006). For example, by using an acquisition/extinction procedure, Matute, Vegas, and De Marez (2002) found that interference tended to disappear when contiguity rather than causal relationships had to be judged. They also showed that subtle indications in postacquisition instructions made participants take into account the information received in the first phase, leading to a sort of recovery-from-interference effect.

Another dependent measure that has been frequently used in interference experiments is skin conductance response in fear conditioning preparations (LaBar & Phelps, 2005; Vansteenwegen et al., 2007; Vervliet, Vansteenwegen & Hermans, 2010). At first glance, one could think that this measure is more likely to reflect fast associative retrieval processes than verbal judgments. However, there is good evidence that knowledge of the CS–US contingency acquired in the absence of CS–US pairings can produce a skin conductance response similar to conditioned fear (see Olsson & Phelps, 2007, for a review). Furthermore, Lovibond (2003) has shown that verbal information after CS–US pairings in a training phase can alter the skin conductance response to the CS in a fear conditioning experiment. Interestingly, Lovibond's study showed that the change observed in the skin conductance response was the result of a complex inference drawn from the relationship learned during the training phase together with the information provided through instructions. Thus, skin conductance response in fear conditioning has already been shown to be the result of complex inferential reasoning processes in some circumstances.

Finally, there is also evidence of interference based on behavioral measures in which participants are subjected to time pressure to respond. For example, Havermans et al. (2005); Nelson et al. (2011); Neumann (2006), and Pineño and Miller (2004) used learning tasks in which participants had to decide whether to respond or not either to prevent undesired consequences or to obtain benefits from outcomes signaled by cues (some of these tasks are based on Arcediano, Ortega, & Matute, 1996). Participants are allowed to respond only during the time (around 3 seconds) in which cues are present. The number of participants' responses is taken as a measure of the extent to which outcomes are expected from the presence of cues. This task is interesting because participants do not have much time to think before responding. Thus, compared with the dependent measures previously discussed, responding in this task is more likely to reflect the result of fast memory retrieval processes. However, there is evidence showing that inferential reasoning modulates participants' responses in this sort of task (Cobos, López, & Luque, 2007; Luque, Cobos, & López, 2008). Though these studies do not conclusively show that inferential reasoning was taking place at test (it might have taken place at the moment of training), the possibility that this could be the case discouraged us from using this kind of task.

This type of evidence has led some researchers to claim that associative processes play no relevant role in human contingency learning in general, which would rely, instead, on reasoning processes and propositional representations of knowledge that can be flexibly used according to task demands (De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009). Given this state of affairs, it seems relevant to provide evidence of the engagement of simpler low level retrieval processes in interference phenomena by using dependent measures that minimize the influence of reasoning processes and, thus, could be more sensitive to such rapid retrieval processes (see also for similar objectives Morís, Cobos & Luque, 2010). In our study, we used a cued response RT task akin to others that have already been used with similar purposes (Burke & Roodenrys, 2000; Tomiczek & Burke, 2008).

In our task, participants had to respond to a mandatory stimulus as soon as possible and without committing errors. The mandatory stimulus consisted of a smiling face (i.e., a smiley) that could appear in any corner of a rectangular surface placed at the center of the screen. Each of the four possible locations of the mandatory stimulus played the role of an outcome and was assigned a specific response key that participants had to press to identify the location of the target smiley. On each training trial, the outcome was preceded by a stimulus consisting of a geometrical figure placed at the center of the rectangular surface. For example, on a given trial, a red square presented at the center of the rectangular surface might be followed by the presentation of the smiley at the top right corner. Thus, the red square would serve as a cue for the occurrence of the outcome. The repeated pairings of both stimuli should lead to the strengthening of the cue-outcome association. As a consequence, the presentation of the cue should activate a representation of the outcome and/or a representation of the response for the outcome even before the onset of this outcome. This activation should facilitate the processing of the outcome or the corresponding response, which, in turn, should speed up learners' identification responses.

A key procedural aspect that should minimize the contribution of inferential reasoning processes is the use of a short stimulus onset asynchrony (SOA), which is the time between the onset of the cue and the onset of the target mandatory stimulus. A short SOA gives very little opportunity for top-down cognitive processes like inferential reasoning to operate. Inferential reasoning processes have been characterized as reflective, slow, and effortful and are thought to demand a good amount of working memory resources (De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009). Conversely, associative retrieval is fast acting, effortless, and requires very little resources from working memory. Because we were especially interested in finding interference effects based on associative retrieval rather than by inferential reasoning processes, we used a short SOA of 300 ms that has previously been shown to reduce the influence of high order cognitive processes (e.g., Neely, 1991; Neely, 1977; Zeelenberg, Pecher, & Raaijmakers, 2003).

In Experiment 1, we established whether our task engaged associatively mediated priming. The objective of Experiment 2 was then to find evidence of interference based on cued response RTs. Finally, Experiments 3 and 4 investigated whether spontaneous recovery and contextual effects, respectively, occurred with the interference paradigm as assessed by the RT measure.

Experiment 1

As shown in Table 2, the interference design used in our experiments consisted of two training phases followed by a test phase which included the same training trials as in the first training phase. The interference effect was assessed by comparing participants' responses on A-1 test trials with responses on B-3 test trials, that is, the interfered and the control relationships, respectively. Interference is said to be found if RTs on A-1 trials are slower than on B-3 trials. However, this interference could be the result of participants' tendency to respond to Outcome 2 after the presentation of Cue A due to the recent A-2 trials of the second training phase. This may slow down participants' responses to Outcome 1. Note that this explanation does not require postulating any priming effect of Cue B on participants' responses to Outcome 3. Thus, we could observe an apparent interference effect even if no learning of the control B-3 relationship is detected. Thus, the aim of Experiment 1 was to provide empirical support for this priming effect due to the cue-outcome relationships learned during training. As shown in Table 1, participants went through two training phases followed by a test phase. During Training Phase 1, participants were trained on three consistent relationships, A-1, B-2, and C-3, and on inconsistent relationships involving Cue D, which could be followed by any of the four possible outcomes with the same probability. The objective of the experiment was to assess whether training on the target A-1 relationship produced a priming effect at test. During the second phase, participants were trained on one consistent relationship, E-4, and several inconsistent relationships involving Cue F, which could also be followed by any of the four possible outcomes with the same probability. Crucially, Phase 2 training included the same number of trials as the second phase of the interference experiments. Thus, learning of the A-1 relationship was measured in a similar condition as the control B-3 relationship used in the interference experiments. The priming effect of Cue A on responses to Outcome 1 was assessed by comparing participants' responses on A-1 test trials with responses on trials in which participants had to learn two new relationships. One of the two control conditions consisted of test trials in which a new cue, G, was systematically followed by Outcome 2. One problem with this control condition is that a new cue might make participants pay more attention to it, thereby enhancing the learning of the cue-outcome relationship. If participants learn very quickly, the priming effect could disappear after a few test trials. Additionally, the novelty of Cue G could raise participants' arousal, which, in turn, might speed up responses to the outcome. For this reason, we added another control condition in which participants had to learn a new relationship between an old cue, D, and Outcome 3. An old cue that has been irrelevant in the past to predict any outcome might retard the learning of a new relationship between such cue and a specific outcome. Thus, D-3 test trials should be a better control for the A-1 test trials to find a priming effect.

Table 1
Design of Experiment 1

Condition	Phase 1	Phase 2	Test
Consistent	A-1	E-4	A-1
	B-2		G-2
	C-3		D-3
Inconsistent	D-1/2/3/4	F-1/2/3/4	

Note. Letters stand for cues and numbers for outcomes.

Method

Participants and Apparatus

A total of 73 participants from the Faculty of Psychology of Málaga University took part in the experiment for course credits. The experiment was carried out in a quiet room with 10 semi-isolated cubicles equipped with Windows XP PCs (Microsoft, U.S.A.). The task was programmed using Visual Basic, 2005 (Microsoft, U.S.A.).

Stimuli

The different cues used were geometrical figures varying in shape and color: a yellow triangle, a red square, a blue rectangle, a green star, a pink heart, an orange half-moon, and a purple cross. The width and height of all these stimuli were between 2.5 and 3 cm. Cues appeared at the center of the PC screen. The outcomes were one of the four possible locations in each corner of an imaginary 9 × 9 cm square at the center of the screen in which a black silhouette of a smiling face with white eyes and mouth (i.e., smiley) could appear. The smiley had a diameter of 2.4 cm and could specifically appear within one of four 3 × 3 cm squared windows that made up the corners of the imaginary bigger square mentioned before. Each of these squares of the corners was 3 cm apart from each other.

Procedure

First, participants read the instructions of the task on the computer screen at their own pace, and the experimenter answered any questions about the task. On each training trial, participants saw a geometric figure in the center of the screen for 200 ms. Then, a blank was presented for 100 ms before the smiley appeared on one of the four possible locations. Thus, the SOA was 300 ms. The mandatory smiley was present until participants responded or until 2000 ms had elapsed at which point an auditory beep encouraged a rapid response. The intertrial interval was 1000 ms, during which a fixation stimulus consisting of a cross placed at the center of the screen was presented. The geometric figures described in the Stimuli section were randomly assigned to the abstract cues of the design shown in Table 1. The random assignment was different for each participant.

Participants used four response keys from the PC keyboard for each of the four possible outcomes. Keys were S, C, L, and M. There was an analogical relationship in the assignment of keys to the different outcomes, according to the key locations in the keyboard. Thus, S was assigned to the outcome localized at the upper left corner; C to the outcome at the left lower corner; L to the outcome at the upper right corner; and M to the outcome at the lower right corner. Participants were told to place their index and middle fingers of both hands on each of the four key responses so that they would not need to look at the keyboard while responding and, thus, they were able to focus their attention on the center of the screen where all the different cues and outcomes appeared. In the inconsistent condition, cues D and F were paired with any of the four outcomes according to a random selection-without-replacement procedure. In the consistent condition, cues were consistently paired with their corresponding outcomes as shown in Table 1.

The task included two training phases and a test phase. The first training phase included 80 trials (20 × 4 trial types). The second training phase included 40 trials (20 × 2 trial types). Finally, the test phase included 60 trials (20 × 3 trial types). The transition from one phase to the next was not marked to participants. Each phase was made up of trial blocks, each one including one trial of each trial type. The order of trials within each block was the result of a random permutation that could differ from one block to the next. Note that there was only one inconsistent trial per block. Thus, the inconsistent cue was paired with a different outcome in each block. The outcomes were randomly chosen without replacement.

Results and Discussion

Only correct responses and RTs between 200 and 1000 ms were selected for the analysis. This way, responses that were too fast were not analyzed nor those for which participants were not attentive. The reason for rejecting very fast responses was to remove trials in which the response was initiated before the onset of the outcome. In such a case, participants would not have followed the instructions, which stated that they had to respond to the outcome rather than to the cue. RTs of responses that did not meet these criteria were substituted by the sample mean corresponding to the same trial type in the same trial block. This might artificially reduce the standard error but, also, might reduce the difference between the mean RTs of the different conditions. If we accept that RTs should tend to be long provided that participants avoid making an incorrect response, substituting RTs of incorrect responses by the sample mean should reduce the mean in each condition. Because errors and RTs greater than 1000 ms are expected to be more frequent in the control than in the consistent (A-1) conditions, the substitution should reduce the mean RTs in the former conditions more than in the latter condition. Consequently, the filter used to analyze the data should, if any, hinder the finding of a priming effect. A significance level of $\alpha = .05$ was used for all of the statistical analyses reported.

The same analysis on test trials RTs was performed in all the experimental series. Because interference might quickly disappear after a few test trials as a result of relearning, the analyses conducted on the data from Experiments 2 through 4 focused on the first four trial blocks of the test phase. Additionally, as the greatest effects were expected to be found on RTs from the first test trial block, planned analyses were conducted on those data. For similar reasons, our analysis of Experiment 1 data focused on the first four trial blocks as well as on the first trial block.

Figure 1 shows participants' RTs on consistent trials A-1, B-2, and C-3, and on inconsistent trials D-1, D-2, D-3, and D-4. To simplify the figure, RTs on inconsistent trials were collapsed into a single RT. Also, RTs within each trial type were averaged on a four-trial-block basis, resulting in five measures (20 blocks/4 blocks) for each trial type (see Figure 1). Although we see a difference between the consistent and the inconsistent trials of the first training phase, the difference in frequency of cue–outcome pairings does not allow us to make a fair comparison between these conditions.

Figure 2 shows participants' RTs for each trial type of the test phase from the first through the fourth trial block. As can be seen, RTs on the first A-1 trial were faster than on the first G-2 trial, which is consistent with a priming effect. However, the difference between A-1 and G-2 seems to disappear from the second test trial onward. This is consistent with participants having learnt the G-2 relationship very quickly, which, in turn, might make more difficult showing a priming effect. To confirm these impressions, a 2 (Cue Condition: A-1 vs. G-2) × 4 (Trials: 1–4) repeated measures ANOVA was performed on participants' RTs, yielding only a significant effect of Trials, $F(3, 216) = 13.81$; $MSE = 5941.26$; $p = .007$; $\eta^2 = .20$. Neither the effect of Cue Condition nor of the interaction was significant (all Fs < 1.72). However, the analysis of the first block of test trials revealed a significant effect of Cue Condition, $F(1, 72) = 4.98$; $MSE = 5366.04$; $p = .029$; $\eta^2 = .06$. This latter result indicates that a priming effect was found when responses on the first A-1 trial were compared with responses on the first G-2 trial.

Regarding A-1 and D-3 trials, Figure 1 seems to show quite a different picture. Participants seem to have been faster throughout the first four test trial blocks on A-1 than on D-3 trials. Thus, as expected, the priming effect seems to have persisted throughout more trial blocks than in the case of the comparison between A-1 and G-2 reported above. This impression was confirmed by a 2 (Cue: A-1 vs. D-3) × 4 (Trials: 1–4) repeated measures ANOVA, which yielded a significant effect of Cue, $F(1, 72) = 7.02$; $MSE = 6509.05$; $p = .01$; $\eta^2 = .09$, and a significant effect of Trials, $F(3, 216) = 9.47$; $MSE = 6080.71$; $p < .001$; $\eta^2 = .11$. Interestingly, the interaction between both factors was not significant, $F(3, 216) = 0.39$; $MSE = 5356.9$; $p = .76$, suggesting that the priming effect benefited from a slow learning of the D-3 relationship. It is also interesting to know that the difference between the A-1 and the D-3 cue condition tends to persist throughout the whole test phase. In fact, Cue, but not the Cue × Trials interaction, was significant even when all the test trials were included in the

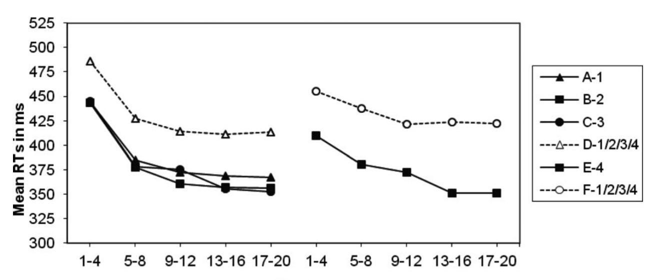

Figure 1. Mean RTs (ms) per trial type within each four-trial block of Training Phases 1 (on the left) and 2 (on the right) of Experiment 1.

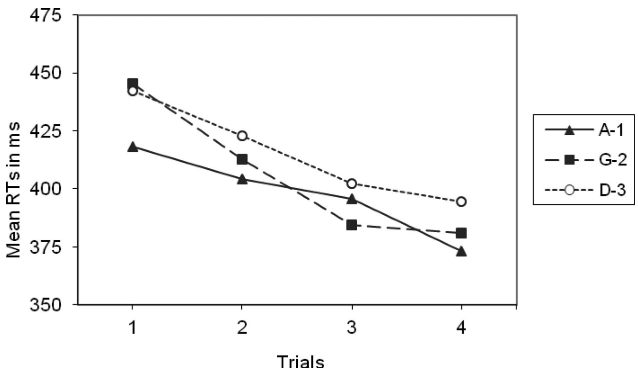

Figure 2. Mean RTs (ms) throughout the first four A-1, G-2, and D-3 trials at test in Experiment 1.

analysis. Finally, when only the first test trial block is analyzed, participants' responses on Trial A-1 were significantly faster than on Trial D-3, $F(1, 72) = 4.45$; $MSE = 4801.5$; $p = .038$; $\eta^2 = .06$.

Because some of the data were excluded from the analysis and were substituted by the sample mean, the effects found might be the result of a nonhomogeneous distribution of the number of replacements across conditions. For the sake of simplicity, we only report the percentage of replacements across conditions in the first four test trial blocks. The percentages of substituted RTs were 4.1%, 3.4%, and 3.1% in A-1, G-2, and D-3 trials, respectively. A Chi-Square test for homogeneous distribution of frequencies revealed no significant difference between conditions, $\chi^2(2) = 0.45$, $p = .798$.

To summarize, the results of Experiment 1 indicate that training participants on the A-1 relationship during the first training phase produces a priming effect of Cue A on responses to Outcome 1 during the test phase.

Experiment 2

This experiment evaluated whether the cued response RT task detected interference. Participant's performance was compared in two within-participant conditions (see Table 2 for the design). In an interference condition, Cue A was consistently paired with Outcome 1 during the first training phase and with a different outcome, Outcome 2, in a second phase. Thus, at test, Cue A should not facilitate the processing of Outcome 1 as a result of the interfering A-2 relationship learnt during the second phase of training. In this case, according to Bouton's theory of interference (see above), a context-dependent inhibitory Cue A–Outcome 1 and excitatory Cue A–Outcome 2 association should be formed. At test, Cue A should inhibit the representation of Outcome 1 and should activate the representation of Outcome 2, as it takes place in the same temporal context of the second phase of training, slowing down RTs to Outcome 1. In the control condition, Cue A was paired with Outcome 1 in the first learning phase whereas in the second phase a new cue, D, was paired with Outcome 2. During test, after training, Cue A should facilitate the processing of Outcome 1 in the control condition as no interfering relationship has been learnt during the second phase of training, and thus RTs will be faster than in the interference condition.

Additionally, interference was also measured using an independent control Cue B (see also Table 2). Cue B was paired with Outcome 3 during the first phase of training and then participants were tested with this control cue, without any further presentation of B-3 trial during training. Thus, interference would also occur if RTs to Outcome 3 on Cue B test trials are faster than those obtained to Outcome 1 on Cue A test trials. For completion of the design, in both conditions, Cue C was paired with Outcome 4 throughout all training. These C-4 trials were a filler trial type to ensure continuity of the cue-outcome relationships programmed during training, some discriminative training during the second phase and that each of the four possible outcomes (i.e., four possible locations of the smiley—see Stimuli section) were used.

Method

Participants, Apparatus and Stimuli

A total of 34 participants from the Faculty of Psychology of Málaga University were trained and tested using the same apparatus, outcomes, and stimuli as Experiment 1 with the addition of a blue-gray lightning figure as an additional cue.

Procedure

The procedure was the same as in Experiment 1 except for the following details. Each participant took part in two independent tasks, one after the other, for each of the two within-subject conditions (interference and control). Both tasks were identical except for the set of cues and outcomes used and the different cue-outcome relationships arranged (see Table 2). Once the first task had been completed, they had a 3-minute break in which they watched a musical video before commencing the second task. The order in which both tasks were performed was counterbalanced across participants.

The geometric figures described in the Stimuli section were split into two groups. Each group of stimuli was used for one of the two tasks participants had to face. For half of the participants, one group was used for the interference condition, whereas the other group was used for the control condition. For the other half, this assignment was reversed. Finally, the geometric figures of each group were randomly assigned to the abstract cues of the design shown in Table 2.

Results and Discussion

The data were subjected to the same filtering process as in Experiment 1. Again, this might have spuriously reduced the

Table 2
Design of Experiment 2

Condition	Phase 1	Phase 2	Test
Interference	A-1	A-2	A-1
	B-3	—	B-3
	C-4	C-4	C-4
Control	A-1	D-2	A-1
	B-3	—	B-3
	C-4	C-4	C-4

Note. Letters stand for cues and numbers for outcomes.

standard error but, also, might have reduced the difference between the mean RTs of the different conditions. As both, more errors and slower RTs (i.e., over 1000 ms) are expected to be more frequent in the interference than in the control condition, the filtering should have reduced to a greater extent mean RTs in the interference condition than in the control condition. Consequently, if anything, the target interference effect should have been more difficult to find.

First of all, we analyzed the data from the first training phase to ensure that any effect found in the test phase could not be explained by differences in the acquisition of the A-1 and B-3 relationships in the different conditions. Figure 3 shows the mean RTs on A-1 and B-3 trials throughout the first training phase, as well as the mean RTs on A-2 and D-2 trials throughout the second training stage of the interference and control conditions. Due to a computer failure, RTs from the C-4 trials were not recorded. Thus, Figure 3 does not include the corresponding data. A visual inspection of the figure reveals no difference between the interference and the control condition regarding the acquisition of the A-1 relationship. Participants' RTs in the last four training trials were analyzed to evaluate that there was no significant difference between both conditions at the end of training. A 2 (Condition: Interference vs. Control) × 4 (Trials: 17–20) repeated measures ANOVA yielded no significant effect (all *F*s < 1.52). In the interference condition, B-3 served as another control condition to detect interference. Thus, we also compared participants' RTs on A-1 and B-3 trials in the last four training trials of the first training stage. A 2 (Cue: A-1 vs. B-3) × 4 (Trials: 17–20) repeated measures ANOVA was carried out yielding no significant effect (all *F*s < 0.75).

Regarding the test phase, only the first four trials were analyzed. Note that relearning of the relationships programmed during the test phase should occur so that the interference effect should diminish progressively. Therefore, as interference is to be expected only during the first trials, the first four test trials were the only ones included in the analysis. First, RTs in A-1 test trials from both Interference and Control conditions were compared. As shown in Figure 4, participants were faster in the control than in the interference condition. As expected, the Condition effect tended to decrease. This is especially apparent when the difference between conditions in the first test trial is compared with the difference between conditions in the remaining test trials. These impressions were confirmed by a 2 (Condition: Interference vs. Control) × 4 (Trials: 1–4) repeated-measures ANOVA, yielding a significant Condition effect, $F(1, 33) = 17.47$; $MSE = 21613.12$; $p < .001$;

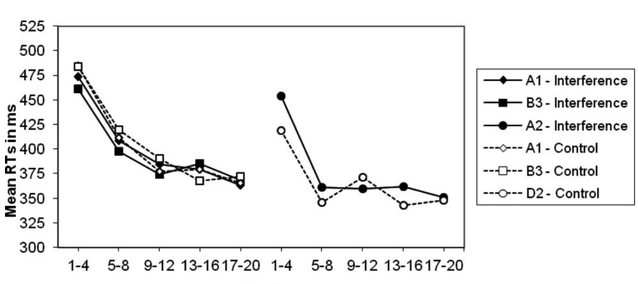

Figure 3. Mean RTs (ms) per trial type within each four-trial block of Training Phases 1 (on the left) and 2 (on the right) of Experiment 2.

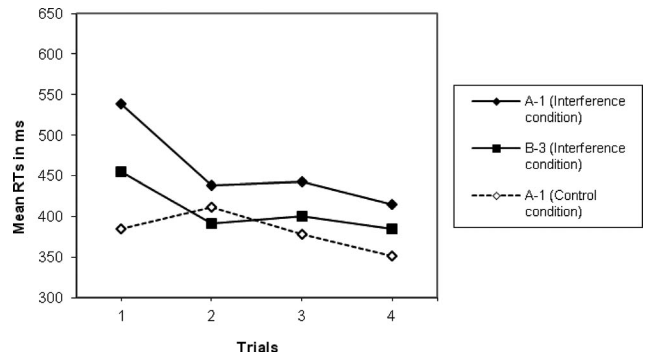

Figure 4. Mean RTs (ms) throughout the first four A-1 and B-3 trials at test in Experiment 2.

$\eta^2 = .34$, a Trials effect, $F(3, 99) = 5.96$; $MSE = 12699.32$; $p = .001$; $\eta^2 = .15$, and a significant Condition × Trials interaction, $F(3, 99) = 5.65$; $MSE = 9928.90$; $p = .001$; $\eta^2 = .14$. The main effect of Condition was a clear indication of an interference effect. The interference effect was also confirmed by an analysis of the first trial, which yielded a significant effect of Condition, $F(1, 33) = 26.36$; $MSE = 15745.42$; $p < .001$; $\eta^2 = .44$.

Second, RTs in A-1 and B-3 test trials in the Interference condition were compared as this would also indicate an interference effect. As can be seen in Figure 4, participants were faster in B-3 than in A-1 trials. To confirm this, a 2 (Cue: A vs. B) × 4 (Trials: 1–4) repeated measures ANOVA was carried out, revealing a significant main effect of Cue, $F(1, 33) = 8.22$; $MSE = 18285.84$; $p = .007$; $\eta^2 = .20$, and a main effect of Trials, $F(3, 99) = 13.64$; $MSE = 10522.57$; $p < .001$; $\eta^2 = .29$. The main effect of Cue indicated an interference effect. This interference effect was also confirmed by an analysis of the first trial block, which yielded a significant effect of Cue, $F(1, 33) = 8.21$; $MSE = 13479.12$; $p = .007$; $\eta^2 = .20$.

The percentages of substituted RTs were 11.8%, 10.3%, and 10.3% in A-1 (Interference condition), A-1 (Control condition), and B-3 (Interference condition) trials, respectively. A Chi-Square test for homogeneous distribution of frequencies revealed no significant difference between conditions, $\chi^2(2) = 0.18$, $p = .913$.

Overall, this pattern of results showed that the cued response task was able to detect an interference effect. Specifically, the comparison between A-1 test trials in both conditions (i.e., Interference vs. Control) and the comparison between A-1 and B-3 test trials within the Interference condition both revealed a significant interference effect. Thus, only the control B-3 relationship was included in the rest of the experimental series (i.e., the Control condition was removed), and this way the procedure was simplified.

Experiment 3

The objective of the experiment was to replicate the spontaneous recovery effect with the cued response task, a classic phenomenon found in previously used interference procedures. In this effect, the mere passage of time after participants have learnt the interfering relationship during the second training phase makes possible an effective retrieval of the relationship learnt during the first phase.

For this, in a delay condition, a temporal delay interval was introduced between the second phase of the learning stage and the test stage (see Table 3). On the other hand, in the immediate condition, the same delay interval was introduced though, in this case, between the first and second phase of the learning stage. Thus, the test phase occurred immediately after the second phase of the learning stage had taken place. A strong attenuation or even disappearance of the interference effect is expected in the delay condition. Thus, RTs showing the retrieval of the formerly interfered A-1 relationship should be faster than those in the immediate condition.

Method

Participants and Apparatus

A total of 48 participants from the Faculty of Psychology of Málaga University were trained and tested using the same apparatus as in Experiment 1.

Procedure

Table 3 shows the two within-participants conditions. In the spontaneous recovery condition, a 100-s temporal delay was inserted between the second phase of the learning stage and the test stage. In the immediate condition, the same temporal delay took place between the first and second phase of the learning stage. The rest of design details were identical in both conditions and the same as in the interference condition of Experiment 2.

The stimuli used throughout the task were as in Experiment 2 except that one less cue was used as there was no D-2 relationship. Participants carried out the task in both temporal delay conditions. Each condition took place as an independent task with a different set of cues. After completion of the first task, participants had a 3-minute break during which they could watch a musical video before commencing the second task. The order in which participants went through the immediate and the delay conditions was counterbalanced.

During temporal delays, participants had to perform a simple card memory game. In the card memory game, 20 cards, grouped in 10 pairs, were presented face-down and randomly located on the computer screen. Participants could turn two cards face-up by clicking on them. If the cards displayed the same image, they had found a pair, and both cards remained upward. Otherwise, participants had to remember their position to find their matching pairs as quickly as possible in subsequent trials. When they had found all pairs, all cards were turned face-down and, again, randomly located. This process was repeated until 100 seconds had elapsed. The card memory game was intended to prevent participants from rehearsing the training trials of any previous training phase. The rest of procedural details were as in Experiment 2.

Table 3
Design of Experiment 3

Condition	Phase 1		Phase 2		Test
Immediate	A-1		A-2		A-1
	B-3	Delay	—	No delay	B-3
	C-4		C-4		C-4
Delay	A-1		A-2		A-1
	B-3	No delay	—	Delay	B-3
	C-4		C-4		C-4

Note. Letters stand for cues and numbers for outcomes.

Results

As in the previous experiment, only correct responses and RTs between 200 and 1000 ms were selected for the analysis. Nonselected data were substituted as explained in the Results and Discussion section of Experiment 1.

Figure 5 shows participants' RTs throughout the training trials of the two training phases. As in Experiment 2, we analyzed participants' responses in the last four trials of the first training phase to compare the effects of training on the learning of the A-1 and B-3 relationships. A 2 (Delay: Delay vs. Immediate) × 2 (Cue: A vs. B) × 4 (Trials: 17–20) within-subjects ANOVA revealed no significant effect (all Fs $<$ 2.463). Because the Delay and the Immediate condition also differed regarding the presence or absence of a delay between the first and the second training phase, we were also interested in analyzing participants' performance at the end of the second training phase. As can be seen in Figure 5, participants seem to have better learned the A-2 and the C-4 relationships in the Immediate than in the Delay condition. This impression is supported by a 2 (Delay: Delay vs. Immediate) × 2 (Cue: A vs. B) ANOVA performed on the averaged RT calculated from the RTs from the four last trials of the second phase, which yielded a significant effect of Delay, $F(1, 47) = 4.63$; $MSE = 21221.29$; $p = .037$; $\eta^2 = .09$. The remaining effects were not significant (all Fs < 2.26).

Regarding the test phase, only the first four trials were analyzed as in the previous experiments for the reasons stated above (see Figure 6). A 2 (Delay: Delay vs. Immediate) × 2 (Cue: A vs. B) × 4 (Trials: 1–4) within-subjects ANOVA of RTs yielded a significant Delay × Cue × Trials interaction, $F(3, 141) = 5.05$; $MSE = 7703.59$; $p = .002$; $\eta^2 = .09$. Planned comparisons were carried out to analyze the source of the three-way interaction found. In the Immediate condition, a 2 (Cue: A vs. B) × 4 (Trials: 1–4) ANOVA showed a significant main effect of Cue, $F(1, 47) = 6.34$; $MSE = 9932.21$; $p = .015$; $\eta^2 = .11$, a significant main effect of Trials, $F(3, 141) = 48.47$; $MSE = 10961.95$; $p < .001$; $\eta^2 = .50$, and a significant Cue × Trials interaction, $F(3, 141) = 6.77$; $MSE = 11445.69$; $p < .001$; $\eta^2 = .12$. On the other hand, within the Delay condition, we found a significant effect of Trials, $F(3, 141) = 15.17$; $MSE = 7101.97$; $p < .001$; $\eta^2 = .24$, as well as a significant Cue × Trials interaction effect, $F(3, 141) = 3.37$; $MSE = 5488.68$; $p = .020$; $\eta^2 = .06$. The main effect of Cue was not significant, $F(1, 47) = 0.08$; $MSE = 12731.35$; $p = .775$; $\eta^2 = .002$.

Although the interaction between Cue and Trials was significant in both the immediate and the delay condition, an inspection of Figure 6 reveals that, in each case, such interaction was found because of very different reasons. In the immediate condition, the interaction was significant because the interference effect was very pronounced in the first trials and tended to disappear in subsequent test trials. In the delay condition, however, the interaction was attributable to continuous subtle changes in the sign of the difference between Conditions A and B throughout the test trials. Such

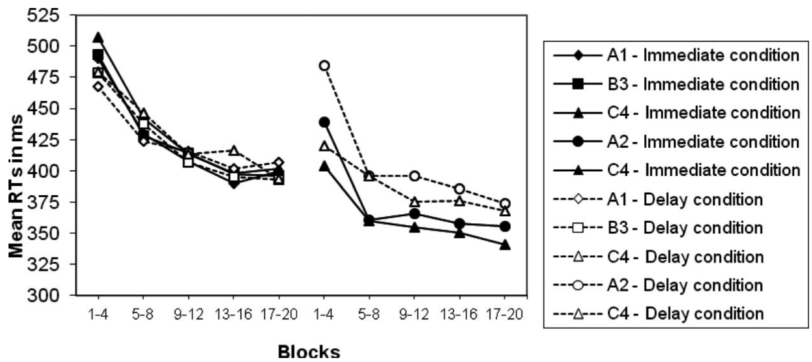

Figure 5. Mean RTs (ms) per trial type within each four-trial block of Training Phases 1 (on the left) and 2 (on the right) of Experiment 3.

differences are not very interesting from a theoretical point of view.

Finally, the analysis performed on RTs from the first test trial block revealed a significant effect of Cue, $F(1, 47) = 11.41$; $MSE = 17026.98$; $p = .001$; $\eta^2 = .19$, a significant effect of Delay, $F(1, 47) = 31.09$; $MSE = 19091.36$; $p < .001$; $\eta^2 = .40$, and a significant interaction Cue × Delay, $F(1, 47) = 4.94$; $MSE = 16088.27$; $p = .031$; $\eta^2 = .09$. This interaction was explained by the simple effect of Cue being significant within the Immediate condition, $F(1, 47) = 12.34$; $MSE = 21174.90$; $p = .001$; $\eta^2 = .21$, but not within the Delay condition, $F(1, 47) = 1.06$; $MSE = 11940.35$; $p = .309$.

As in the previous experiments, we analyzed the distribution of the number of replaced RTs across conditions to rule out that the effects found are the result of an experimental artifact. The percentages of substituted RTs were 13% and 9.9% in A-1 and B-3 trials, respectively, in the Immediate condition, and 5.2% and 7.8% in A-1 and B-3 trials, respectively, in the Delayed condition. However, as the most important result is the interaction effect, we performed a Chi-Square for independence between Cue and Delay, yielding a nonsignificant difference between the observed and expected frequencies, $\chi^2(1) = 1.8$, $p = .179$.

Discussion

The overall pattern of results showed the effect of Trials as expected and the effectiveness of the Delay manipulation. Specifically, in the Immediate Condition RTs in A-1 were significantly slower than in B-3 trials, showing an interference effect, whereas in the Delay condition, no significant differences were found between RTs in A-1 and B-3 trials. Thus, participants successfully retrieved the otherwise interfered A-1 relationship when a temporal delay was inserted between the second phase of training and the test phase, showing a spontaneous recovery effect with our cued response task.

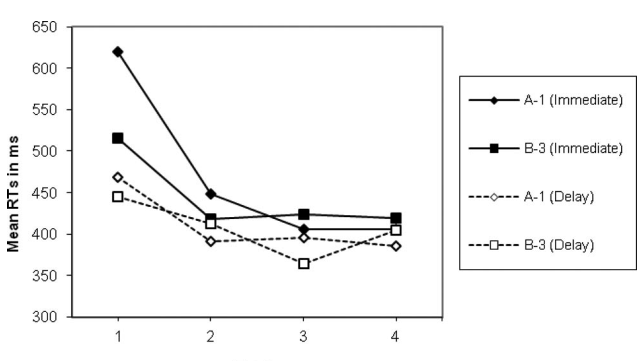

Figure 6. Mean RTs (ms) throughout the first four A-1 and B-3 trials at test in Experiment 3.

As the order of trials at test was randomized, the resulting order might have contributed to the results found. Specifically, it is quite reasonable to expect higher RTs for the first trial of the test phase than for the remaining trials. Note, also, that the greatest difference between A-1 and B-3 is precisely found when the first trial of each trial type is considered. Thus, the greater interference effect in the immediate condition might be the result of having more A-1 than B-3 trials in the first place in the immediate condition and the reverse frequency pattern in the delay condition. However, the frequency distribution of trial types in the first place of the test phase was almost identical in both conditions. Specifically, the frequency of A-1 and B-3 trials occurring first was 21 and 14, respectively, in the immediate condition, and 21 and 12, respectively, in the delay condition.

Another alternative explanation of our results is related to the difference found in the second training phase between the Delay and the Immediate condition, that is, participants learned better in the latter condition than in the former. Note that, in the delay condition, there was no time interval between the end of the first phase and the beginning of the second phase. This might have produced a sort of proactive interference of the previously acquired A-1 relationship on the acquisition of the A-2 relationship of the second phase. This, in turn, would have led to a reduction of the interference effect at test. Alternatively, in the immediate condition, the delay between Phase 1 and Phase 2 training might have reduced the proactive interference thereby enhancing the acquisition of the Phase 2 relationships. This, in turn, might have produced a greater interference effect at test. In summary, the recovery of the A-1 learning in the delay condition could have been the result of the absence of delay between the end of Phase 1 and the beginning of Phase 2.

Despite the explanation of spontaneous recovery based on the absence of delay between Phase 1 and Phase 2 has some empirical support, it is not compatible with the overall pattern of results found. According to this account, we should not have found an interference effect in the interference condition of Experiment 2. In fact, such condition was identical to the delay condition of Experiment 3 except for the delay between Phase 2 and the test phase in the latter experiment. Thus, the interference condition of Experiment 2 provides an alternative control condition that allows gaining some information about the contribution of the absence of delay on the spontaneous recovery found. To compare the interference condition of Experiment 2 with the delay condition of Experiment 3, we conducted a 2 (Experiment: 2 vs. 3) × 2 (Cue: A vs. B) × 4 (Trials: 1–4) mixed ANOVA on RTs from the first four trials of the test phase, which yielded a significant effect of Cue, $F(1, 80) = 6.71$; $MSE = 15022.58$; $p = .011$; $\eta^2 = .07$, Trials, $F(3, 240) = 28.44$; $MSE = 8512{,}97$; $p < .001$; $\eta^2 = .26$, Cue × Trials, $F(3, 240) = 2.78$; $MSE = 6692.69$; $p = .041$; $\eta^2 = .03$, and, most importantly, a significant effect of Cue × Experiment, $F(1, 80) = 5.06$; $p = .027$; $\eta^2 = .06$. Given the results reported above concerning each Experiment condition, this interaction clearly indicates that the interference effect was significantly greater in the interference condition of Experiment 2 than in the delay condition of Experiment 3. Thus, the most plausible explanation of the results found in Experiment 3 is that the spontaneous recovery was attributable to the delay between the end of Phase 2 and the test phase.

Experiment 4

Experiments 2 and 3 showed the effectiveness of the cued response procedure to detect interference and the spontaneous recovery of the interfered cue-outcome relationship. The objective of the present experiment was to show another effect that has been traditionally found with verbal judgments procedures, the context change effect. Based on the design of Experiment 3, the different phases of the learning and test stages of Experiment 4 took place in different contexts. Specifically, the first phase of the learning stage took place in Context X and the second phase in a different context, Context Y (see Table 4). Furthermore, test took place in Context X in the XYX condition, whereas it took place in Context Y in the XYY condition. The context change effect will be said to have occurred if RTs are slower in A-1 than in B-3 trials of the test phase in the XYY condition but not in the XYX condition. In this last condition, RTs should be equivalent in A-1 and B-3 trials or, at least, the interference should be reduced. In other words, interference should be greater if the test takes place in the same context (Context Y) as the second training phase, in which participants are presented with A-2 trials. A recovery of the expression of the A-1 relationship learned in the first training phase should occur if the test takes place in a different context (Context X) than that for the second training phase.

Table 4
Design of Experiment 4

Condition	Phase 1	Phase 2	Test
XYY	Context X	Context Y	Context Y
	A-1	A-2	A-1
	B-3	—	B-3
	C-4	C-4	C-4
XYX	Context X	Context Y	Context X
	A-1	A-2	A-1
	B-3	—	B-3
	C-4	C-4	C-4

Note. Letters stand for cues and numbers for outcomes.

Method

Participants and Apparatus

A total of 37 participants from the Faculty of Psychology of Málaga University took part in the experiment for course credits and were trained and tested using the same apparatus as in Experiment 1.

Procedure

All procedural details and stimuli were as in Experiment 3, with the exception of the contexts and that no delay was introduced between training phases. Each participant took part in both experimental conditions. Each condition took place as an independent task with a different set of cues. After completion of the first task, participants had a 3-minute break during which they watched a musical video before commencing the second task. The order in which they completed both tasks was counterbalanced. The different contexts programmed were different color backgrounds of the screen together with different background sounds that were played during the task. Colors used were orange, turquoise, purple, and yellow. The background sounds were sounds from a tropical jungle, from a busy bar, from a stormy rain, and music from percussion instruments. Each context was made up of a specific combination of screen background and sound background. The four contexts used were orange screen + tropical-jungle sound, turquoise screen + busy bar sound, purple screen + stormy rain sound, and yellow screen + music from percussion instruments. These contexts were split into two groups so that each group was assigned to the XYY and XYX conditions according to a counterbalance procedure.

Results and Discussion

As in previous experiments, only correct responses and RTs between 200 and 1000 ms were selected for the analysis. Nonselected data were substituted as explained before.

Figure 7 shows participants' RTs throughout the first and second training phases. A 2 (Test Context: XYY vs. XYX) × 2 (Cue: A vs. B) × 4 (Trials: 1–4) within-subjects ANOVA was performed on RTs from the last four trials of the first phase. No significant effect was found (all Fs < 2.5).

Regarding the test phase, an inspection to Figure 8 reveals that participants were slower on Cue A than on Cue B trials within the XYY condition, which indicates an interference effect. This difference almost disappeared within the XYX condition; that is, the interference effect tended to decrease in the XYX condition. To confirm these impressions, a 2 (Test context: XYY vs. XYX) × 2 (Cue: A vs. B) × 4 (Trials: 1–4) within-subjects ANOVA was performed on RTs. A significant main effect of Cue, $F(1, 36) = 8.53$; $MSE = 12618.21$; $p = .006$; $\eta^2 = .19$, and Trials, $F(3, 108) = 39.46$; $MSE = 11820.27$; $p < .001$; $\eta^2 = .52$ were found, and also a significant Test Context × Cue, $F(1, 36) = 7.67$;

$MSE = 8704.26$; $p = .009$; $\eta^2 = .17$, and Cue $\times$ Trials, $F(3, 108) = 2.69$; $MSE = 8610.88$; $p = .049$; $\eta^2 = .07$, interactions were found.

Planned comparisons were carried out within each Test Context condition to evaluate a possible different interference effect in the XYY and the XYX conditions. Within the XYY condition, a 2 (Cue: A vs. B) $\times$ 4 (Trials: 1–4) repeated measures ANOVA yielded a significant effect of Cue, $F(1, 36) = 16.69$; $MSE = 10304.98$; $p < .001$; $\eta^2 = .31$, and a significant effect of Trials, $F(3, 108) = 25.45$; $MSE = 10223.56$; $p < .001$; $\eta^2 = .41$. The Cue $\times$ Trials interaction was not significant, $F(3, 108) = 1.80$; $MSE = 9905.57$; $p = .15$; $\eta^2 = .04$. The same analysis within the XYX condition only yielded the significant effect of Trials, $F(3, 36) = 17.58$; $MSE = 11957.33$; $p < .001$; $\eta^2 = .32$. Neither the effect of Cue, $F(1, 36) = .22$; $MSE = 11017.49$; $p = .642$, nor the interaction between Cue and Trials, $F(3, 108) = 1.10$; $MSE = 8549.08$; $p = .351$; $\eta^2 = .03$, were significant.

Finally, the analysis on RTs from the first trial block only yielded a significant effect of Cue, $F(1, 36) = 9.63$; $MSE = 15311.23$; $p = .004$; $\eta^2 = .21$. Neither the effect of Test Context, $F(1, 36) = 0.63$; $MSE = 23301.55$; $p = .43$, nor of the interaction between both factors, $F(1, 36) = 1.71$; $MSE = 18452.50$; $p = .200$, were significant. Despite the nonsignificant interaction effect, planned comparisons revealed that the interference effect was significant in the XYY condition, $F(1, 36) = 10.18$; $MSE = 15487.84$; $p = .003$; $\eta^2 = .22$, but not in the XYX condition, $F(1, 36) = 1.17$; $MSE = 18275.89$; $p = .287$. The results found in the analysis of the first four trial blocks suggest that the absence of a significant Cue $\times$ Test Context interaction effect in the first trial block is attributable to a lack of power. Given that the interference effect seemed to have persisted throughout the first four trial blocks in the XYY condition, the data from such trial blocks might have provided more statistical power to detect the crucial interaction effect.

The percentages of substituted RTs were 10.1% and 8.8% in A-1 and B-3 trials, respectively, in the XYY condition, and 14.2% and 14.2% in A-1 and B-3 trials, respectively, in the XYX condition. For the same reason as in the previous experiment, we performed a Chi-Square for independence between Cue and Test Context, yielding a nonsignificant difference between the observed and expected frequencies, $\chi^2(1) = 0.09$, $p = .770$.

Thus, the results showed a significant reduction of the interference effect in the XYX condition. Specifically, Cue A facilitated responses to Outcome 1 in the XYX condition compared with the XYY condition. In the latter condition, RTs to Outcome 1 that

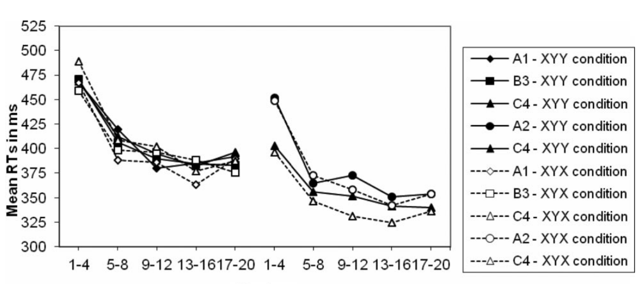

Figure 7. Mean RTs (ms) per trial type within each four-trial block of Training Phases 1 (on the left) and 2 (on the right) of Experiment 4.

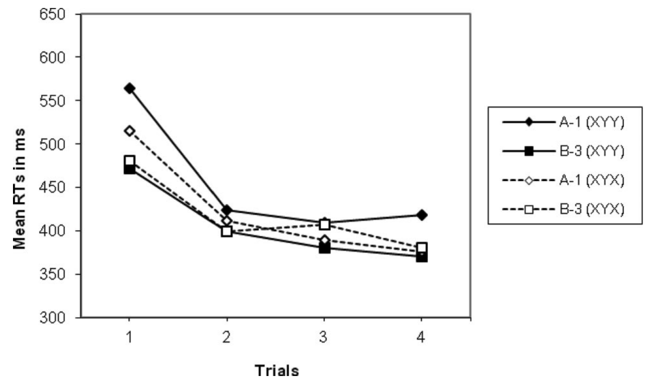

Figure 8. Mean RTs (ms) throughout the first four A-1 and B-3 trials at test in Experiment 4.

followed Cue A were significantly slower than those to Outcome 3 following Cue B, whereas no corresponding differences were detected in the XYX condition. Thus, a significant recovery of an interfered learning attributable to context change was detected with the cued response task developed.

Again, this pattern of results cannot be explained on the basis of the frequency distribution of A-1 and B-3 trials occurring first during the test phase. A-1 trials were slightly more frequent in the XYY (13 times) than in the XYX (11 times) condition. But the frequency of B-3 trials occurring first in the XYY condition (15 times) almost doubled the frequency of B-3 trials in the XYX condition (8 times). Moreover, the most frequent trial type occurring first in the XYY condition was B-3. Thus, if anything, RTs on B-3 trials should be slower in the XYY than in the XYX condition, which should decrease the interference effect. However, as can be seen in Figure 8, RTs on B-3 trials were almost identical in the XYY and the XYX condition, and, as above mentioned, the interference effect was greater in the XYY than in the XYX condition.

General Discussion

The most common associative explanation of interference is based on a retrieval failure (or response interference) rather than on the unlearning of the interfered relationship. The processes responsible for this retrieval are considered the result of an associative activation mechanism that is thought to be fast, automatic, and to require few attentional resources. Despite this, all previous studies aimed to provide evidence supporting the associative account of interference are based on the use of dependent measures that give participants ample opportunity to engage in inferential reasoning to respond. The engagement of such processes might be particularly likely in those cases in which participants are required to make inferential judgments, which have extensively been used as a dependent measure in interference experiments. Thus, up-to-date, there is no data that can convincingly show that the interference effects found are produced by fast activation processes rather than by inferential reasoning processes. The objective of the present study was to test whether interference phenomena can be observed by using a cued response task designed to detect fast activation processes. Participants were trained to associate a series of cues (figures) with a series of outcomes (a smiling face that could appear in four different locations) that were associated with specific response keys that had to be pressed on the outcome presentation as fast as possible. At test, participants were retrained with the interfered relationship (A-1) and with the relationship that served as a control condition (B-3). Interference was assessed by comparing participants' responses in A-1 trials with participants' responses in B-3 trials. Because a short SOA of 300 ms was used, response facilitation was very unlikely to be caused by slow inferential reasoning processes (Neely, 1991; Neely, 1977).

Experiment 1 assessed whether a priming effect could be observed as a result of training. For this purpose, participants were trained on a relationship, A-1, in very similar conditions to the B-3 relationship used in the interference experiments as a control condition. As a result, a priming effect of Cue A on responses to Outcome 1 was observed both in the test phase. In Experiment 2, interference was observed in that RTs in A-1 pairings were slower than in B-3 pairings at test. In Experiment 3, we found spontaneous recovery by using the same task. All participants performed the task in two conditions: a delay and an immediate condition. The results showed a significant interaction between delay and interference treatment attributable to interference being significant only in the immediate condition. We also added further analyses to ensure that the effect found was a genuine spontaneous recovery effect. Finally, a context-change effect was found in Experiment 4. In this case, we found an interference effect in an XYY condition in which the physical context at test was the same as in the second training phase. However, the interference effect became nonsignificant in an XYX condition in which the physical context at test was the same as in the first training phase, and differed from that used in the second training phase.

Overall, our results are clearly compatible with associative theories of interference. The present study is particularly supportive of the idea that interference and recovery from interference phenomena in humans are the result of fast acting retrieval processes based on associative activation mechanisms. To our knowledge, this is the first evidence of interference phenomena showing a strong implication of fast activation processes. Because of the short SOA used between cues and outcomes (300 ms), it is very unlikely that the effects found be the result of reflective thinking or inferential reasoning working at test. Of course, it would be over the top to say that our task prevents any form of high cognitive process. However, it is hard to see how in such a little amount of time the sort of inferences favored by reasoning accounts may explain, for example, contextual effects in interference. According to this proposal, participants might strategically attend to the context at test as far as they become aware of its informative value. This strategic increase in the attention dedicated to the context might contribute to produce a context-change effect. For example, to explain a context-change effect, participants should be able to infer that Cue A will no longer be followed by Outcome 2, as the A-2 relationship is only valid in its training context. Then, Cue A will be followed by Outcome 1. And all this chain of inferences should be performed in as little time as 300 ms, the time interval between the onset of the cue and the onset of the outcome, and in such an efficient way as to speed up responses to Outcome 1 to the same extent as in the control condition. Surely, this kind of inference would require a long time and a good amount of resources that should be detracted from the RT task thereby producing a negative effect on participants' performance given the time pressure used as well as the speed of the sequence of events during test.

Inferential reasoning processes might have contributed to produce the effects found by modulating the associative processes. Consider, for example, the spontaneous recovery found in Experiment 3. In the delay condition, during the time interval in which participants were performing the card memory game, participants might have been rehearsing the A-1 trials in anticipation of the presentation of Cue A at test. This, in turn, could have counteracted the interference of A-2 trials. This argument does not work so well in the case of the context-change effect found in Experiment 4. It is very unlikely that the context change made participants dedicate a good amount of resources to mentally rehearse the A-1 trials of the first phase while, at the same time trying to respond to the outcomes and attend to the cues under time pressure in a situation in which events rapidly succeeded each other. In any case, even if some room is left for inferential reasoning to help explain the data, an associative activation mechanism or another fast process must still be postulated to account for effects that require the participation of processes within a time window as short as 300 ms.

The way we implemented the procedure to detect interference does not allow us to know whether the interference and recovery effects found are attributable to retrieval or to response processes. For example, the interference found in the experimental series might be explained either as a retrieval failure (participants failed to retrieve Outcome 1 from Cue A) or as a response interference (the response to Outcome 2 interfered with the response to Outcome 1 even if Outcome 1 was successfully retrieved). As said in the Introduction, Bouton's (1993) theory can be easily adapted to both forms of interference. Additionally, our experiments do not allow us to draw conclusions about the learning content. In this sense, participants could have learned cue–outcome or cue–response associations. Of course, the same could be said regarding many interference experiments in animal conditioning. And, again, Bouton's (1993) theory should not be viewed as exclusively concerned with S–S associations. It is rather a general framework that is perfectly compatible with S–R associations. Thus, whatever the kind of interference and the learning content may be, what is really important is that the interference phenomena detected with our task are compatible with an associative account as that proposed by Bouton (1993).

As said in the Introduction, the recovery experiments might have two different interpretations. The absence of interference in the delay and the XYX conditions might be the consequence of a failure of Cue A to elicit the response to Outcome 2. According to this explanation, it would not be necessary to invoke any recovery of the capacity of Cue A to facilitate responses to Outcome 1. In this sense, the recovery results would not be, strictly speaking, a true recovery effect as long as it would not be due to a recovery of the expression of the A-1 learning. On the other hand, the recovery effects might be interpreted as something beyond a loss of the capacity of Cue A to elicit responses to Outcome 2. Specifically, the absence of a significant difference between RTs on A-1 and B-3 test trials might also indicate a recovery of the capacity of Cue A to facilitate responses to Outcome 1. In this sense, we would have a true recovery effect as long as responses on A-1 test trials would be an expression of the A-1 learning. Whether we favor one or the other interpretation depends, in turn, on whether we consider responses on B-3 test trials as an expression of the B-3 learning during Phase 1 or not. Results from Experiment 1 strongly suggest that training participants on the B-3 relationship during the first training phase must have produced a priming effect of Cue B on responses to Outcome 3 at test. Thus, RTs from B-3 test trials might reasonably be taken as an expression of the B-3 learning. According to this, the most reasonable interpretation of the recovery effects is that the recovery of the expression of the A-1 learning at test plays a role in explaining the absence of interference.

Another point that deserves our attention is the nature of the learning mechanisms responsible for the effects observed. The results found are quite consistent with associative learning principles as those postulated by Bouton's (1993) theory. But the fact that the effects found are those predicted by associative theories of learning at test does not necessarily rule out a nonassociative account of learning. Specifically, inferential reasoning processes might have played an important role in the encoding of context, whether physical or temporal. For example, in Experiment 4, the change from Context X to Context Y might have made participants infer that the context is important to disambiguate the meaning of Cue A as a predictor. Once participants made such inference, they might have paid attention to the context, resulting in its storage together with the cue and the outcome. The difference between this explanation and Bouton's associative theory is that the former assumes that learners are actively searching for a solution to disambiguate the meaning of Cue A and that the encoding of the context requires the previous and explicit intention to do it.

Despite all these considerations, our experiments clearly show that fast activation processes have an important role in explaining interference phenomena of human contingency learning. To our knowledge, this is the first study in which interference is measured by using a test that is highly sensitive to fast activation processes. In our view, the use of techniques such as the one used in our task can improve our understanding of the processes involved in interference experiments to a great extent. In the long term, we should be able to know whether the processes responsible for interference and recovery from interference are bottom-up processes as those envisaged by associative theories or whether inferential reasoning can contribute to the results found in the literature. In the first case, a more direct comparison could be made between interference in humans and in nonhuman animals.

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