Renewal effects in interference between outcomes as measured by a cued response reaction time task: Further evidence for associative retrieval models

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Abstract

Two experiments demonstrated renewal effects in interference between outcomes in human participants. Experiment 1 revealed a XYX renewal effect whereas Experiment 2 showed a XYZ renewal effect. The results from both experiments conformed to Bouton's (1993) theory of interference and recovery from interference, and contradicted the predictions derived from alternative accounts. Unlike previous demonstration of renewal effects, a cued response reaction time task was used, able to detect the effects of fast retrieval processes based on associative activation and that allowed little impact of inferential reasoning.

Retroactive interference between outcomes (hereafter interference) refers to a decrement in the expression of a learned relationship between events due to the later acquisition of another relationship. In human contingency learning, this effect is typically observed when participants are repeatedly exposed to cue-outcome presentations in which a given cue (say Cue A) is followed by an outcome (say Outcome 2) after having been trained on Cue A-Outcome 1 pairings. In such cases, the expression of the A-1 relationship learned in the first place decreases. An interesting aspect of the interference effect is that it has been shown to depend on the context in which participants are probed. Specifically, interference occurs if participants are probed with A in the same context of the interfering A-2 trials, and tends to disappear if the test takes place in a different context (Nelson et al., 2011; Neumann, 2006; Pineño & Miller, 2004; Rosas, Vila, Lugo, & López, 2001). In the latter case, the expression of the A-1 relationship learned in the first place tends to recover. This context dependency of interference has commonly taken as evidence that the first relationship (A-1) is not simply unlearned. Rather, the two different meanings of the cue as a predictor of the two outcomes remain stored in memory, and the context plays a crucial role in the control of retrieval and response processes when the cue becomes ambiguous.

As the context has been shown to be important for solving ambiguity in interference experiments, an interesting question concerns the mechanism responsible for the context dependency of interference. The common approach to answer this question has been provided by associative learning theories. Within the associative framework, the most accepted explanation of the context dependency of interference is Bouton's (1993) theory, which was initially formulated within the domain of animal conditioning. According to this theory, the A-1 pairings of the first training phase lead to an excitatory association between the representations of Cue A and Outcome 1, whereas the A-2 pairings of the second training phase lead to two additional associations: An excitatory association between the representations of Cue A and Outcome 2, and an inhibitory association between the representations of Cue A and Outcome 1. Crucially, to solve the ambiguity of Cue A, the associations learned in the second place become context-dependent. The context of the interfering phase, Phase 2, works as an and-gate that conditions the functionality of the associations learned in the second place (see Figure 1, Case A). Thus, for Cue A to activate the representation of Outcome 2, the context of the A-2 pairings must be present. Likewise, the inhibitory Cue A-Outcome 1 association also requires the presence of such context to produce its inhibitory effect. As a consequence, interference only occurs if participants are tested in the context of the interfering trials. Alternatively, if the test phase takes place in a context different from that of the interfering trials, interference tends to disappear because neither the inhibitory Cue A-Outcome 1 association nor the excitatory Cue A-Outcome 2 association will be effective. Interestingly, studies in animal conditioning have provided good evidence of context switch effects supporting Bouton's mechanism. Crucially, in these experiments, researchers have gone to some length to rule out alternative explanations based on direct associations between the contexts and the outcome (Bouton & King, 1983; Bouton and Swartzentruber, 1986; Rescorla, 2008; we elaborate more on this below).

Bouton's theory (and associative theories in general) of interference and context effects implies that participants' responses at test are the result of retrieval processes mediated by associative activation processes. Associative activation processes, in turn, are thought to be fast, incidental, and to demand few working memory resources. Despite the central role of fast associative retrieval processes in the explanation of context effects on interference, the dependent measures used in most of the experiments conducted so far are based on participants' judgments about the relationships between cues and outcomes. Verbal judgments, by allowing participants have plenty of time to respond to verbal test questions, allow for the influence of inferential reasoning processes on participants' performance. Thus, in some cases, interference phenomena might be caused by reasoning processes rather than by a retrieval failure. For example, if participants learn that Medicine A causes Symptom 1 in Context X and, later on, Symptom 2 in Context Y, they could infer that the effects of the medicine depend on the context; hence, the low causal ratings are given to the A-1 relationship when participants are tested in Context Y and the high ratings when the test takes place in Context X. Note that this account is very different from saying that participants do or do not successfully retrieve the first outcome because of the high or low activation of its representation. Given this possibility, there is no way to know to what extent the context effects observed in verbal judgments could genuinely be attributed to associative retrieval processes.

To address this issue, González-Martín, Cobos, Morís, and López (2012) conducted several experiments on interference in which, instead of verbal judgments, the dependent measure was based on the extent to which the cues speeded up responses to outcomes in a cued response reaction time task. In this task, participants had to respond to a mandatory stimulus as soon as possible 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 centre 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 centre of the rectangular surface. For example, on a given trial, a red square presented at the centre 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. To preclude as much as possible responses based on inferential reasoning processes, which 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), the onset of the outcome occurred 300 ms after the onset of the cue; i.e., a stimulus onset asynchrony (SOA) of 300 ms was used. This SOA has previously been shown to reduce the influence of high order cognitive processes in other priming experiments (e.g., Neely, 1991; Neely, 1977, Zeelenberg, Pecher, & Raaijmakers, 2003). Moreover, in a recent study, Sternberg and McClelland (2012) showed that the incidence of inferential reasoning processes tended to disappear when a task very similar to that designed by González-Martín et al. was used instead of a more conventional learning task.

By using the task just described, González-Martín et al. (2012) found a context effect on interference in one of the experiments. In that experiment, participants performed two tasks (one after the other), each one in a different condition. In Condition XYY, participants learned the A-1 relationship in Context X during Phase 1, then learned the A-2 relationship in Context Y during Phase 2, and, finally, were trained again on the A-1 relationship in Context Y (see the design in the Old Cues condition in Table 1) during the test phase. Condition XYX was the same except for the fact that the test phase took place in Context X. Thus, the A-1 training during the test phase allowed an assessment of the context modulation of interference from the A-2 training in the second phase. Additionally, in both conditions, participants were trained on B-3 trials alternated with A-1 trials in Phase 1 and in the test phase. This provided a control condition to test whether the A-2 trials caused an interference effect on the expression of the A-1 relationship previously learned. Participants were also presented with filler C-4 trials during the three training phases. Using this design, interference was only found in the XYY condition as evidenced by longer reaction times in A-1 trials than in B-3 trials in the test phase. This difference was especially noticeable in the first trials and tended to disappear in subsequent trials. In the XYX condition, response times in the A-1 and B-3 trials did not differ. Furthermore, the context effect on interference was confirmed by the significant interaction effect of the context and the type of trial factors.

One limitation of the design used by González-Martín et al. is that it does not discriminate between Bouton's (1993) and other alternative accounts of context effects on interference. As has been pointed out by Nelson et al. (2011), an XYX recovery effect, such as that found by González-Martín et al., may be explained by simpler associative theories on the basis of the formation of direct associations between the representation of the context and the representation of the outcome. Therefore, this context effect is compatible with the alternative explanation illustrated in Case B of Figure 1. In this case, Context Y serves the role of a simple stimulus that acquires a direct inhibitory association with Outcome 1. This inhibitory learning arises because, during the first phase, Cue A acquires an excitatory association with Outcome 1, leading to an expectation of the occurrence of Outcome 1 during the first trials of the second phase. However, as the expected outcome does not occur in Phase 2, Context Y becomes a signal of its absence thereby generating an inhibitory Y-1 association that protects Cue A from complete extinction of its excitatory association with Outcome 1. As a consequence, if the test phase takes place in Context X, Cue A would activate the representation of Outcome 1, or the response associated with this outcome, more than if the test phase takes place in Context Y.

Given the possible role of contextual inhibition, it is important to discriminate between renewal and simple generalization decrement in contextual inhibition (Nelson et al., 2011). The term *renewal* is used to refer to context switch effects, such as the XYX context effect, when the recovery from interference cannot be explained by direct associations between the contexts and the outcome. If the context switch effect were due to direct associations between the contexts and the outcome, the phenomenon would not differ from generalization decrement in terms of the underlying mechanism.

In conclusion, the results found by González-Martín et al. (2012, Experiment 4) cannot be taken as an unequivocal demonstration of renewal, and therefore cannot be interpreted as evidence supporting the operation of Bouton's mechanism within a cued reaction time task. The objective of the present study was to assess the extent to which the context modulation of interference observed by González-Martín et al. was due to renewal or generalization decrement. For this purpose, we used the same design and task but added further condition that allowed us to assess the contribution of an inhibitory association between Context Y and Outcome 1.

Experiment 1

González-Martín et al. (2012) showed a context switch effect but their study was not conclusive regarding the nature of the mechanism underlying this effect. Specifically, their results, an XYX recovery effect, were also compatible with the idea that Context Y played the role of a simple stimulus that acquired an inhibitory association with Outcome 1 by signaling its absence (Case B in Figure 1). The objective of Experiment 1 was, then, to evaluate whether a genuine renewal effect may be obtained with a procedure thought to engage associative activation processes during retrieval at test.

The rationale of the design used in Experiment 1 is based on the idea that, if the interference effect found in the XYY context condition is due to an inhibitory association between the representation of Context Y and the representation of Outcome 1 (or the response for that outcome), the mere presence of Context Y should inhibit the representation of Outcome 1 (or the response for that outcome), which would explain the longer RTs found in Outcome 1 trials compared with Outcome 3 trials. Thus, even if Cues A and B were not present at test, the presence of Context Y should slow down participants' responses to Outcome 1 compared with Outcome 3. A way of testing this prediction would be to include test trials in which Outcomes 1 and 3 are present but following a set of two new cues, D and E, respectively. As these cues have not been presented before, no previous association could have been established with the outcomes that may be affecting differently participants' RTs to Outcomes 1 and 3. Thus, if participants' RTs to Outcome 1 were slower than to Outcome 3 this difference should be taken as evidence favorable to the inhibitory properties of Context Y. Table 1 shows the design of Experiment 1. Two groups of participants were tested either in a different context from Phase 2, Group XYX (i.e., the context change group), or in the same context, Group XYY (i.e., the no context change group). Furthermore, each group of participants went through two experimental conditions in which the cues presented during test were either old (i.e., already presented during training) or new (i.e., not presented during training). The conditions that included old cues during test (both in the XYX and XYY groups) served to replicate the context effect obtained by González-Martín et al. (2012, Experiment 4). In the New cues conditions, Cues D and E were followed by Outcomes 1 and 3, respectively.

In Group XYY, if the context effect observed in the old cues condition was due to a direct inhibitory association between Context Y and Outcome 1, responses in B-3 trials should be faster than responses in A-1 trials, as the presence of Context Y should be inhibiting Outcome 1. Additionally, if this inhibitory association between Context Y and Outcome 1 is formed, responses in D-1 and E-3 from the new-cues condition should also differ. Note that although both cues are new, the inhibition of Outcome 1 due to the presence of Context Y should still make responses to Outcome 1 in D-1 trials slower than to Outcome 3 in E-3 trials. However, in Group XYX, during test, no Outcome 1 inhibition is expected as

Context Y is not present. Thus, responses in B-3 and A-1 trials within the old-cues condition should not differ, nor should those in E-3 and D-1 trials within the new-cues condition. Thus, responses in D-1 and E-3 trials should only differ in Group XYY but not in Group XYX.

By contrast, if Context Y modulates retrieval on grounds other than direct associations with Outcome 1, in Group XYY, during test, responses in B-3 trials should be faster than responses in A-1 trials but no differences should be expected between responses in D-1 and E-3 trials. Additionally, in Group XYX during test, responses in target trials A-1 and B-3 should not differ nor should responses in D-1 and E-3 trials. Thus, responses in D-1 and E-3 trials should not differ either in Group XYY or in Group XYX. In sum, changes in context (i.e., XYY vs. XYX) should modulate the difference between responses in D-1 and E-3 trials according to the inhibitory Context Y-Outcome 1 hypothesis but not according to the renewal hypothesis.

Method

Participants and apparatus

A total of 58 participants from the Faculty of Psychology of Málaga University took part in the experiment for course credits (28 participants in Group XYX and 30 participants in Group XYY). The experiment was carried out in a quiet room with 10 semi-isolated cubicles equipped with Windows XP PCs (Microsoft, USA). The task was programmed using Visual Basic 2005 (Microsoft, USA).

Stimuli

As in González-Martín et al. (2012), 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, a purple cross, and a turquoise circle. The width and height of all these stimuli were between 2.5 and 3 cm. Cues appeared at the centre of the PC screen. The outcomes were one of the four possible locations in each corner of an imaginary 9 x 9 cm square at the centre 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 x 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 for the task individually and after that, the experimenter answered any questions concerning the task. On each training trial, participants saw a geometric figure in the centre of the screen for 150 ms. Then, a blank screen was presented for 50 ms before the smiley appeared on one of the four possible locations. Therefore, the SOA was 200 ms (at variance with González-Martín et al.'s procedure in which a SOA of 300 ms was used). 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 inter-trial interval was 1000 ms, during which a fixation stimulus consisting of a cross placed at the centre of the screen was presented. The geometric figures described in the Stimuli section were randomly assigned to the alphabetic cues of the design shown in Table 1. The same procedure was used to assign the four possible locations of the smiley to the four abstract outcomes of the design shown in Table 1. Individual randomized assignments of the cues and outcomes were made for each participant and for each of the two independent tasks that participants had to face (see below).

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 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 appeared.

In accord with the experimental design (see Table 1), two independent groups of participants carried out the task, the XYY (no context change group) and the XYX group (context change group). Participants in each of these groups carried out two independent tasks, the old-cues and the new-cues task, one after the other in a counterbalanced order within each group. Each of these tasks involved different set of cues and contexts. As a consequence, the stimuli used for Cues A through D and Contexts X and Y in one task were different from the stimuli used for the other task. In addition, each task included two training phases and a test phase. The first training phase included 60 trials (20 presentations of each trial type x 3 trial types). The second training phase included 40 trials (20 presentations of each trial type x 2 trial types). Finally, the test phase included 60 trials (20 presentations of each trial type x 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. After completion of the first task, participants had a 3 minutes 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 sets so that each set was assigned to the new-cues and the old-cues conditions according to a counterbalance procedure. Orthogonal to this counterbalance procedure, within each set of context stimuli, we counterbalanced the assignment of the roles of X and Y to the two context stimuli.

Results and discussion

As in González-Martín et al. (2012), only correct responses and reaction times (RTs) longer than 100 ms and shorter than 1000 ms were selected for the analysis. The upper limit was 1000 ms, as in González-Martín et al. (2012). However, the lower limit was 100 ms instead of the 200 ms time used by González-Martín et al. This way, responses that were too fast (i.e., responses arguably initiated before the onset of the outcome despite the instructions received) were not analyzed nor those ones for which participants were too slow (i.e., they were not attentive enough). Unlike González-Martín et al. (2012), we analyzed the second training phase of our experiments, which only included two trial types. With such an easy task, the rejection of RTs below 200 ms would have entailed the elimination of more than 25% of all the measures registered. Therefore, we decided to relax this lower limit to 100 ms so that only 8.1% of all the measures were not included in the analysis. A significance level of $\alpha = .05$ was used for all of the statistical analyses reported in the experimental series.

Figure 2 shows the RTs across both training phases in the old-cues and the new-cues conditions. We were interested in checking whether at the end of the first training phase there were differences in the RTs obtained on target outcomes that may explain the expected effects at test. These expected effects were as follows: a) an interaction effect between the test context and the outcome (Outcome 1 vs Outcome 3) in the old-cues condition, as we expected to find a renewal effect in this old-cues condition; b) a three-way Context x

Outcome x Type of Cue (Old vs New) interaction, as no renewal effect was expected in the new-cues condition; c) an Outcome or interference effect in Group XYY but not in Group XYX within the old-cues condition. Another prediction from Bouton's theory is that a context effect should be found in A-1, but not in B-3 test trial. Finally, as we did not expect any inhibitory effect of Context Y in the new-cues condition, it was predicted the absence of any interaction between Context and Outcome as well as no difference between Outcome 1 and Outcome 3 in Group XYY from the new-cues condition. Therefore, the last 4 trial blocks of the first training phase were analyzed using a Linear Mixed Models (LMM) analysis. Given the temporal selection criterion of RTs adopted, a more standard analysis of variance would have required an extensive use of an imputation method for missing data, with its ensuing problems as none of them is optimal. The LMM analyses tested for specific effects as all the analyses were derived from clear theoretical predictions. A compound symmetry covariance structure was used in all cases as this was the structure that yielded an overall best fit. Thus, we first tested the three-way Context (XYX vs. XYY) x Type of cue (Old vs. New) x Outcome (1 vs. 3) interaction in the last 4 Trial blocks (Blocks 17 through 20). Within the old-cues condition, the mean RTs found in A-1 and B-3 trials in the XYY group were 323 ms and 327 ms, respectively, and 348 ms and 344 ms, respectively, in Group XYX. Within the new-cues condition, the mean RTs found in A-1 and B-3 trials in Group XYY were 338 ms and 351 ms, respectively, and 355 ms and 349 ms, respectively, in Group XYX. The LMM analysis yielded a non-significant three-way interaction effect, [$F(7, 384.206) = 1.07$, $p = 0.383$]. It may be argued that assessment of a significant three-way interaction demands greater statistical power. However, the pattern of results obtained is very different from that we expected to find in the test phase. For example, RTs in A-1 and B-3 trials within Group XYY from the old-cues condition were nearly identical, with a small trend against a possible interference effect. In the same condition, RTs in Group XYX were also very similar. Thus, the pattern of results in the old-cues condition was far from the Context x Outcome interaction that was expected in the analyses of RTs from the test phase. The new-cues condition is less relevant because we did not expect to find any significant effect on RTs from the test stage.

Regarding the second phase, we only analyzed RTs from the last four A-2 trials (note that C-4 were filler trials). In the old-cues condition, the mean RTs found were 264 ms and 269 ms in Groups XYY and XYX, respectively. In the new-cues condition, the means were 274 ms and 266 ms in Groups XYY and XYX, respectively. The expected renewal effect at test might be explained by a better learning of the A-2 relationship in Group XYY than in Group XYX in the old-cues condition, but not in the new-cues condition. However, an LMM analysis to test for the Context x Type of cue interaction did not reveal any significant effect [$F(3, 159.18) = 0.23$, $p = .879$]. The mean RTs at the end of the second training stage were very similar to each other. Thus comparable performance was achieved in all conditions and groups, both at the end of Phases 1 and 2.

Figure 3 shows the main results obtained during the test stage for the old-cues and the new-cues conditions. As predicted by the renewal hypothesis, the figure shows a modulating effect of the test context on the interference effect in the old-cues condition but not in the new-cues condition. Specifically, in the old-cues condition, participants in Group XYY were slower in A-1 than in B-3 trials, especially in the first test trial, which is evidence of an interference effect. However, in the Group XYX, the interference effect was absent. By contrast, in the new-cues condition, RTs for the various test trials did not differ across the context conditions. The statistical analyses confirmed these impressions.

Only the first block of trials was considered for this statistical analysis. Note that the test phase entailed the relearning of the relationships programmed during Phase 1 so that the target interference effect should diminish its magnitude rapidly. Thus, the first block of trials should be regarded as a more reliable and sensitive measure to detect an interference effect across the different conditions. In other words, participants' performance during this first block of test trials should be minimally affected by the relearning of the cue-outcome relationships from Phase 1 and therefore, a more appropriate measure of interference effects.

An LMM analysis was carried out to test for the three-way Context x Type of Cue x Outcome interaction which was marginally significant, $F(7, 141.13) = 1.81$, $p = .09$, $\eta_p^2 = .08$. We also analyzed the Context x Outcome interaction in the old-cues condition which was significant, $F(3, 84.84) = 3.38$, $p = .022$, $\eta_p^2 = .11$. This effect is consistent with the renewal effect that can be appreciated in Figure 3A. This interpretation is supported by a significant effect of Outcome in the old-cues condition in Group XYY, $F(1, 25.5) = 10.72$, $p = .003$, $\eta_p^2 = .3$, but not in Group XYX [$F(1, 25.53) = 0.001$, $p = .982$]. Also, as expected from Bouton's theory, in the old-cues condition, the test context significantly affected participants' responses in Trial A-1, $t(46) = 2.19$, $p = .033$, $\eta^2 = .09$, but not in Trial B-3 [$t(50) = -0.22$, $p = .827$]. Regarding the new-cues condition, the analysis of the Context x Outcome interaction yielded a non-significant effect [$F(3, 77.97) = 0.39$, $p = .763$]. We did not perform further analysis in this condition because, as can be seen in Figure 3B, participants tended to respond somewhat faster to Outcome 1 than to Outcome 3 with this tendency being more pronounced in Group XYY than in Group XYX. This pattern of results is just the opposite of what should be expected if Context Y had acquired an inhibitory association with Outcome 1.

Considering the whole pattern of effects revealed by the analyses, it is fair to say that we found a renewal effect. In other words, the interference effect was clearly modulated by the test context, and such modulating effect was not based on a direct inhibitory association between the representation of Context Y and the representation of Outcome 1.

Because some of the data were excluded from the analysis, the effects found might be the result of a distribution of excluded data across conditions that was inconsistent with the pattern of mean RTs across conditions. Therefore, the pattern of results obtained may have been conditioned by this artifact. To evaluate this potential artifact, we report the percentage of exclusions across conditions in the first test trial block. Within the old-cues condition, the percentages of excluded RTs in A-1 and B-3 trials were 26.7% and 16.7, respectively in Group XYY, and 7.1 and 10.7, respectively, in Group XYX. Within the new-cues condition, the percentages of excluded RTs in Trials D-1 and E-3 were 20% and 10%, respectively, in Group XYY, and 17.9 and 10.7, respectively, in Group XYX. As can be seen, the pattern of exclusions is consistent with RTs. Taking into account that almost all the exclusions were due to errors, and, secondarily, to RTs longer than 1000 ms, more exclusions were expected to be found in Trial A-1 than in Trial B-3 in Group XYY. This difference should disappear in the XYX condition. Thus no trade-off was observed between exclusions and RTs. As the context effect on interference reduces to an interaction between the context factor and the type of outcome, we used a Chi-Square to test for independence between such factors in each type-of-cue condition. This test revealed no significant departure from independence in the old-cues condition, $\chi^2(1) = 2.37$, $p = .123$, nor in the New cues condition, $\chi^2(1) = 0.11$, $p = .739$. Although the percentage of replacement for some test trials may seem high, note that a short SOA of 200ms was used and, thus, the task may have been difficult for participants. In fact, most of the exclusions were due to participants' erroneous responses.

Though the order of trials at test was randomized, it is necessary to ensure that the actual order of trials did not condition the pattern of results reported. Given that participants' performance during the first block of test trials is especially sensitive to interference effects, the distribution of trial types occurring in the first test trial may have conditioned the results obtained. To address this issue, we present the number of times that each trial type was the first test trial across the different experimental conditions. In the XYY group, the distribution was 12 A-1, 11 B-3, and 7 C-4 trials in the old-cues condition; and 11 D-1, 7 E-3, and 12 C-

4 trials in the new-cues condition. In the XYX group, the distribution was 12 A-1, 10 B-3, and 6 C-4 trials in the old-cues condition; and 9 D-1, 8 E-3, and 11 C-4 trials in the new-cues condition. This distribution was relatively homogeneous and so it is unlikely that the distribution of trial types conditioned the results obtained.

The pattern of results reported concerning the old-cues condition replicated the results found by González-Martín et al. (2012, Experiment 4). An interference effect was found in the group that did not entail a context change (i.e., XYY group) and a recovery from the interference effect in the group for which the context had changed (i.e., XYX group). Specifically, RTs on A-1 trials were slower than on B-3 trials in the XYY group, whereas RTs for those target trials did not differ in the XYX group.

The main objective of the experiment, though, was to evaluate the role of the context in this recovery from interference phenomenon, as the old-cues condition did not allow us to distinguish between a true renewal effect and a simpler explanation based on the formation of a direct Context Y-Outcome 1 inhibitory association. According to the inhibitory hypothesis, context changes should also affect differences between the target test trials in the new-cues condition (i.e., RTs should be slower on D-1 than on E-3 test trials in the XYY group but of a similar magnitude in the XYX group). Note that the design used was especially sensitive to capture RT differences between the old- and the new-cues conditions as this factor was manipulated on a within-participant basis, whereas context changes were manipulated on a between-participant basis. Despite this difference, the pattern of results obtained was inconsistent with the predictions derived from the inhibitory hypothesis. Specifically, no inhibitory context association was detected as similar RTs were detected in D-1 and E-3 trials in the XYY group in which this association should have been evidenced. Alternatively, the whole pattern of results is consistent with a renewal effect. In other words, the context switch effects found are not based on direct associations between the contexts and the outcomes, as evidenced by the absence of differences between RTs in D-1 and E-3 test trials both in the XYX and in the XYY group.

The interpretation of results as interference or recovery from interference effects within our task may raise some concern, though. Any genuine interference or recovery from interference effect should involve a target comparison with a control condition that effectively entails a facilitation effect due to consistent cue-outcome pairings. This control condition, within our design, is the B-3 relationship as it has been described before. However, this facilitation effect has not independently been confirmed within our design. In other words, the design used did not allow us to measure whether B-3 cue-outcome pairings during the first phase speeded up responses at test to Outcome 3 when preceded by cue B, compared to a proper control condition. Thus, it may be questioned whether differences between target responses to A-1 and B-3 trials may be genuinely regarded as interference or whether the absence of differences between responses to these target trials may be regarded as recovery from interference effects. To avoid this problem, González-Martín et al. (2012), in their Experiment 1, showed that training a series of consistent cue-outcome pairings in a first phase, just as the B-3 relationship in the present study, caused facilitation responses at test when the outcome was preceded by the cue. Facilitation was evidenced by showing faster RTs to target than to control test trials in which the outcome was preceded by an unrelated cue (either old or new). A similar comparison may also be made between responses in B-3 and in E-3 test trials in the first block. For this purpose, we collapsed the XYY and XYX groups, and conducted an LMM analysis to test for the effect of Type of Cue on participants' responses to Outcome 3. The analysis revealed that RTs in E-3 (M = 566 ms) trials were longer than RTs in B-3 trials (M = 506 ms), $F(1, 51.4) = 4.83$, $p = .032$, $\eta_p^2 = .09$. However, we should be cautious with the interpretation of this result because the proper control condition to detect a priming effect should include an old cue rather than a new cue. Note that our task is a special case of the associative repetition priming paradigm. In this paradigm, the detection of a priming effect requires the use of an old (rather than a new) cue in the control condition (see, for example, McKoon & Ratcliff, 1979; or, more recently, Morís, Cobos, Luque, & López, in press).

Experiment 2

In the second experiment we again evaluated predictions derived from the renewal and contextual inhibition hypotheses but in a different context switch design. As illustrated in Table 1, the design was the same as that employed in the first experiment except for the test context. In the present experiment the interference observed in the XYY condition was assessed against an XYZ condition in which the text contest Z was novel (Bouton, 1993). According to the renewal hypothesis (Bouton, 1993), XYX and XYZ are forms of context switch effects that are mediated by the same mechanism of interference whereby the context serves as an and-gate that conditions the functionality of the associations learned in the second phase. Therefore, renewal does not require that the test takes place in the same context as that in which the first association was learnt. The contextual inhibition hypothesis predicts that difference between the test performance of Groups XYY and XYZ in the old-cues condition should also be observed in the new-cues condition.

Method

Participants and apparatus

A total of 119 participants from the Faculty of Psychology of Málaga University took part in the experiment for course credits (62 participants in Group XYY and 57 participants in Group XYY). The same apparatus as that described for Experiment 1 was used here.

Stimuli and procedure

Again, two independent groups of participants carried out the task, the XYY (no context change group) and the XYZ group (context change group). Participants in each of these groups carried out two independent tasks, the old-cues and the new-cues tasks. Each of these tasks involved different set of cues and contexts. As a new context, Context Z was included, two new contexts were created, one for each of the two types of cue condition tasks. One of the contexts was a green color background and sounds from a henhouse. The other context was a pink color background and sounds from sea waves. The counterbalancing procedure was as in Experiment 1 except for the stimuli that played the role of the contexts. As the test took place either in Context Y or in Context Z, we held constant the stimulus that played the role of Context X and counterbalanced the stimuli that played the role of Contexts Y and Z. Note, however, that, as in Experiment 1, two completely different sets of stimuli were used for the two tasks, the old-cues and the new-cues task. In all other respects the stimuli and procedures were the same as those used in Experiment 1.

Results and discussion

Again and for the reasons stated above, only correct responses and reaction times between 100 and 1000 ms were selected for the analysis. RTs of responses that did not meet these criteria were excluded and were not substituted through any imputation method.

Figure 4 shows participants' RTs across the first and second training phases in the old-cues and new-cues conditions. As in Experiment 1, we checked whether there were differences in the RTs obtained on target outcomes at the end of the first training phase that may bias the interpretation of the target test results. We started by a LMM analysis of the three-way Context x Type of Cues x Outcome interaction in the last 4 Trial blocks (Blocks 17-20). Within the old-cues condition, the mean RTs found in A-1 and B-3 trials in the XYY group were 330 ms and 347 ms, respectively, and 324 ms and 332 ms, respectively, in Group XYZ. Within the new-cues condition, the mean RTs found in Trials A-1 and B-3 in Group XYY were 317 ms and 316 ms, respectively, and 319 ms and 322 ms, respectively, in Group XYZ. The LMM analysis of the three way interaction yielded a significant effect, *F*(7, 736.41) = 2.28, p = .027, η_p^2 = .02. This interaction effect must be due to a Type II error because, as can be seen in Table 1, during the first training stage, participants received virtually the same treatment in all experimental conditions. Our main concern, however, was to ensure that this interaction was not due to a Context x Outcome interaction in the old-cues condition. Importantly, the LMM analysis revealed a non-significant effect for this interaction [F(3, 306.01) = 1.76, p = .156]. Note, also, that the pattern of results found in the old-cues condition is quite different from what we expected to find at test. In general, there was a tendency for RTs in A-1 trials to be shorter than in B-3 trials, which could hardly explain the renewal effect expected at test. In the new-cues condition, all mean RTs were very close to each other, and, consequently, no effect was found.

Regarding the second phase, as in Experiment 1, we only analyzed RTs from the last four A-2 trials. In the old-cues condition, the mean RTs found were 256 ms and 265 ms in Groups XYY and XYZ, respectively. In the new-cues condition, the means were 257 ms and 254 ms in Groups XYY and XYZ, respectively. The expected renewal effect at test might be explained by a better learning of the A-2 relationship in Group XYY than in Group XYZ in the old-cues condition, but not in the new-cues condition. However, an LMM analysis to test for the Context x Type of cue interaction did not reveal any significant effect [F(3, 366.78) = 1.12, p = .343]. Again, mean RTs at the end of the second training stage were similar. In summary, comparable performance was achieved in all conditions and groups, both at the end of Phases 1 and 2.

Figure 5 shows participants' RTs in the first four blocks of trials from the test stage in the old-cues and the new-cues conditions. In the old-cues condition, participants from the XYY group responded more slowly in A-1 than in B-3 trials, showing an interference effect. In contrast, this pattern of responses was reversed in the XYZ group, showing a renewal effect. In the new-cues condition, no differences between responses' RTs to target Outcomes 1 and 3 were found in any of the two context groups.

The statistical analyses carried on the first block of test trials, as in the previous experiment. Given that this first block should be minimally affected by the relearning of the cue-outcome relationships that occurred across test trials, it may be regarded as a more appropriate measure to detect interference effects. As in Experiment 1, we started by analyzing the three-way Context x Outcome x Type of Cue interaction. As in the previous experiment, the LMM analysis revealed a marginally significant interaction effect, $F(7, 292.36) = 1.88$; $p = .072$; $\eta_p^2 = .04$. Given that high-order interactions require more statistical power to be significant, it is not surprising that the three-way interaction was only marginally significant in both experiments. However, the replication of this effect indicates that, in both experiments, the old-cues and the new-cues conditions differed regarding the extent to which the test context modulated the interference effect. This interpretation was supported by a LMM analysis of the Context x Outcome interaction within each type-of-cue condition. In the old-cues condition, the analysis yielded a significant effect of the interaction, $F(3, 156.3) = 2.95$; $p = .034$; $\eta_p^2 = .05$, which was explained by a significant effect of outcome in the XYY group, $F(1, 55.2) = 4.16$; $p = .046$; $\eta_p^2 = .07$, but not in the XYZ group, $F(1, 49.3) = 3.2$; $p = .08$. In other words, the interaction Context x Outcome may be interpreted as a context effect on interference: An interference effect was found in the XYY group but not in the XYZ group. Another way of interpreting the Context x Outcome interaction would be in terms of a differential effect of context change on responses in A-1 trials compared with B-3 trials, which is also predicted from Bouton's theory. In this case, a t-test for independent samples revealed a significant difference between groups XYY and XYZ in A-1 trials, $t(91) = 2.73$, $p = .008$, $\eta^2 = .08$, but not in B-3 trials, $t(102) = -0.55$, $p = .586$. In the new-cues condition, the Context x Outcome interaction was not significant, $F(3, 148.77) = 0.41$; $p = .747$. Also, as can be seen in Figure 5B, RTs, in general, tended to be shorter in D-1 than in E-3 trials with this tendency being slightly more pronounced in Group XYY than in Group XYZ. This pattern of results is incompatible with an inhibitory effect of Context Y on responses to Outcome 1.

Overall, this whole pattern of results replicated the results from Experiment 1 and in doing so, extended these results to a situation in which the change of context involved a completely new context rather than a return to the original context in which Phase 1 training had taken place. As before, no inhibitory effect was found in the new-cues condition. This null result contradicts the hypothesis that a direct inhibitory association is formed between Context Y and Outcome 1.

Due to the data exclusion procedure described above, as in Experiment 1, the effects found might be the result of an inconsistent distribution of the number of excluded RTs across conditions compared with the pattern of mean RTs across conditions. To discard these effects, we report the percentage of excluded RTs across conditions in the first test trial block. Within the old-cues condition, the percentages of excluded RTs in A-1 and B-3 trials were 27.5 and 8.1, respectively, in Group XYY, and 15.8 and 17.5, respectively, in Group XYZ. Within the new-cues condition, the percentages of excluded RTs in D-1 and E-3 trials were 16.1 and 19.4, respectively, in Group XYY, and 19.3 and 14, respectively, in Group XYZ. As in Experiment 1, a strong coherence between excluded RTs and mean RTs was found. A Chi-Square test for independence between Context and Type of Outcome performed on the percentages of exclusion revealed a significant departure from independence in the old-cues condition, $\chi^2(1) = 6.58$, $p = .010$, but not in the new-cues condition, $\chi^2(1) = 1.06$, $p = .302$. As in Experiment 1, most of the excluded RTs were due to participants' erroneous responses, and, secondarily, to RTs longer than 1000 ms. These results show that there was no trade-off between data exclusion and RTs, and therefore the pattern of results found in RTs cannot be attributed to an artifact due to the exclusion process.

Again, it would be necessary to make sure that the order in which the different trial types occurred during test did not condition the pattern of results reported, despite the fact that the order of trial types within each block of test trials was randomly determined. As in Experiment 1, we present the number of times that each trial type was the first test trial across the different experimental conditions. In the old-cues condition, the frequency distribution across the different trial types was 19 A-1, 21 B-3, and 21 C-4 trials in the XYY group, and 17 D-1, 24 E-3, and 16 C-4 trials in the XYZ group. In the new-cues condition the distribution was 18 D-1, 24 E-3, and 20 C-4 trials in Group XYY, and 18 D-1, 24 E-3, and 15 C-4 trials in Group XYZ. This distribution of trial types was reasonably homogeneous and it is hard to see how this distribution of trial types may have conditioned the results obtained.

In sum, these results extend the renewal effect obtained in Experiment 1 to an XYZ renewal. First, in the old-cues condition, an interference effect was shown in the XYY group, whereas a renewal effect was found in the XYZ group. This renewal effect allowed us to show that the first cue-outcome association was context independent. It could have been that this first association also became context dependent, as in the case of the second association learnt. Thus, renewal might have been alternatively produced as a consequence of an excitatory association between Context X (i.e., the first phase context) and Outcome 1. As long as test trials took place in a new context, Z, this hypothesis can be discarded.

In addition, as in Experiment 1, we did not observe the pattern of results that would be expected from the hypothesis that Context Y becomes an inhibitor for Outcome 1. Participants' RTs to D-1 and E-3 test trials did not differ in any of the contexts where these trials were tested. Thus, the XYZ renewal effect cannot be attributed to the operation of such an inhibitory association.

Finally, we conducted an LMM analysis to test for the difference between responses in the B-3 and in the E-3 test trials in the first block. The difference found was consistent with a priming effect since responses in B-3 trials tended to be about 6 ms faster than in E-3 trials. However, in this case, the difference did not reach a significant level, $F(1, 97.61) = 0.33$, $p = .569$. As noted above, however, the most appropriate control condition to detect priming effects should involve the presence of an old rather than a new unrelated cue (see González-Martín et al., 2012 for an elaboration on this claim).

General Discussion

The objective of the present study was to find evidence for renewal in humans by using a learning task designed to detect the effects of fast retrieval processes based on associative activation. For this purpose, we used González-Martín et al.'s (2012) cued response reaction time task, which was designed to study fast retrieval processes in interference experiments with a questionable impact of inferential reasoning. In Experiment 1 we used an XYX renewal design very similar to that used by González-Martín et al. in their Experiment 4. In that experiment, González-Martín et al. found that participants were slower on trials subject to interference (A-1) than on control trials (B-3) in the XYY condition but not in the XYX condition. That is, interference tended to disappear when participants were tested in the same context in which the A-1 relationship was learned. However, this context effect cannot be interpreted as a true renewal effect because it can be explained on the basis of a direct inhibitory associative relationship between Context Y and Outcome 1. To rule out this alternative explanation, Experiment 1 included a new condition in which A-1 and B-3 test trials were replaced by D-1 and E-3, where D and E were new cues that had not been previously presented to participants. If Context Y had developed an inhibitory association with Outcome 1 during the second training phase, the presence of this context at test should have slowed down participants' responses in D-1 trials compared to E-3 trials. At the same time, this difference between D-1 and E-3 trials should have disappeared in the XYX condition. Contrary to this prediction, differences in RTs to D-1 and E-3 trials were not modulated by the test context. Furthermore, responses on D-1 trials were not slower than on E-3 trials when participants were tested in Context Y. Despite this finding, we replicated the context effect found by González-Martín et al. when A-1 and B-3 trials were used at test. That is, the interference effect was significantly greater in the XYY condition than in the XYX condition. As a consequence, the pattern of results yielded by Experiment 1 was consistent with a true renewal effect but inconsistent with an interpretation of the context effect in terms of a direct relationship between the contexts and the outcome or, in other words, in terms of generalization decrement.

In Experiment 2 we extended our focus of interest to the XYZ renewal effect. This renewal effect would provide more compelling evidence for discounting the idea that the direct associations between the interference context Y and the outcome contribute in the context switch effects. As expected, we found that the context modulated the difference between participants' responses on A-1 and B-3 trials. Specifically, there was an interference effect in the XYY condition but not in the XYZ condition. This context effect cannot be explained by postulating an inhibitory associative relationship between Context Y and Outcome 1 because the manipulation of the context did not exert any influence on participants' responses to Outcomes 1 and 3 when they were preceded by the new cues D and E, respectively. Nor did the context factor interact with any other factor in this condition. Additionally, responses to Outcome 1 tended to be a bit faster than to Outcome 3 regardless of the context of the test phase. Thus, no evidence of an inhibitory relationship between Context Y and Outcome 1 was found.

Overall, the pattern of results found in Experiments 1 and 2 can reasonably be interpreted as evidence for renewal in humans. In our experiments, we did not find any evidence of direct associations between the contexts and the outcomes that could explain the context change effects observed. In this respect, our results are in line with Nelson et al.'s (2011) finding and add to the scarce evidence showing true renewal in humans. In their experiments, participants played a video-game task modeled on the conditioned suppression procedure used to study fear conditioning. The experiment was designed to detect context switch effects due to direct associations between the contexts and the outcome. Although a context switch effect was found, the pattern of results obtained led the authors to conclude that these direct associations played no relevant role. However, there are important differences between Nelson et al.'s and our approach to the study of the effects of context switch on interference. Whereas our interference paradigm was based on counter-conditioning, Nelson and colleagues used a design based on extinction.

Other aspects of our task make it a viable alternative paradigm to study the role of associative processes in renewal effects in humans. One aspect contributing to this aim was the short SOA used between the onset of the cue and the onset of the outcome. Another one was the incidental nature of the task, i.e., participants could perform the task on the solely basis of the outcome (the location of the smiley). The different phases of the tasks were not explicitly marked to participants and no extra-time was added for context switch, which took place within the 1 s inter-trial interval between trials. The stimuli used were not framed within any causal scenario that could have promoted any sort of causal reasoning. Moreover, the contexts used (combinations of screen-color backgrounds and sounds) did not require any semantic interpretation and were arbitrarily related with the stimuli used as cues (geometrical figures) and outcomes (the location of the smiley). For example, the relationships between cues and outcomes were arbitrary and were not framed within any causal scenario that may trigger causal reasoning processes. In a similar vein, the extent to which performance in the task requires a semantic interpretation of cues and outcomes is reduced to a minimum compared with many other tasks used to study renewal and interference (see, for example, the tasks used by Nelson et al., 2011; Neumann, 2006; Pineño & Miller, 2004; Rosas et al., 2001; Rosas & Callejas-Aguilera, 2006). Finally, the stimuli used as contexts were not labeled or presented in a way so as to induce a semantic interpretation. They consisted of colors and sounds with distinct perceptual features. Crucially, participants did not receive any instructions to pay special attention to the contexts. Although it would be unwarranted to claim that these features are sufficient to completely preclude the use of previous structured knowledge (causal or not) mediated by complex and abstract representations, there are grounds for arguing that our task provides a more suitable means to study associative processes in humans than more standard tasks.

Despite these considerations, it would be premature to conclude that any particular experimental procedure completely precludes the intervention of one type of process or the other, especially as the associative learning literature has not yet provided a comprehensive list of boundary conditions for the intervention of inferential or associative processes. In this sense, the list of requirements our procedure accomplishes may not be regarded as exhaustive (see also Morís, Cobos, Luque, & López, in press for further discussion of these requirements). Thus, participants might have been using some strategies to form expectations or to modulate fast retrieval processes. Of course, the short SOA used in our experiments did not easily allow participants to engage in cognitive sophisticated, time-consuming thinking process. But we cannot completely discard the possibility of using very simple rules such as 'every time the context changes, there is a change in the Cue A-Outcome pairings' (see Pineño & Miller, 2004).

Part of our results replicate the results found in other studies based on verbal judgments and on procedures more permeable to inferential reasoning. However, this concordance should not be taken as indicating that the processes underlying participants' performance in our task are the same as those underlying this performance in more standard preparations. In fact, this question is beyond the objectives pursued here. Further research will be needed to find out whether differences in the procedure used in different studies also make a difference in terms of the processes involved. Instead, the purpose of the present experimental series has been to show renewal effects based on the operation of fast memory retrieval via activation processes, which is highly compatible with the operation of associative processes. This objective may be said to have been satisfied according to the list of requirements met by our task.

Finally, another issue concerns the extent to which Rosas and Callejas-Aguilera's (2006) proposal applies to our data. According to their proposal, context specificity is a consequence of the enhanced attention paid to the context when a cue becomes ambiguous. Crucially, this attentional process generalizes to contexts other than the context in which the interfering training has taken place and also affects cue-outcome pairings involving non-ambiguous cues. To support this proposal, Rosas and Callejas-Aguilera (2006, Experiment 4) conducted an experiment in which participants faced two learning tasks, one after the other. The crucial finding was that participants' ratings to the cue-outcome relationships learned in the second task were context-specific only if some cues had become ambiguous during the first of these tasks. Interestingly, this context specificity affected cue-outcome relationships involving non-ambiguous cues, and occurred even though the cues and outcomes involved in each task were different and interpreted within different causal scenarios. Although Rosas and Callejas-Aguilera have supported their proposal with animal conditioning experiment (Bernal-Gamboa, Callejas-Aguilera, Nieto, & Rosas, in press; Rosas & Callejas-Aguilera, 2007), Nelson, Lombas, and León (2011) have found opposing results. As a consequence, it remains to be known whether the effects found by Rosas and Callejas-Aguilera (2006) can be generalized to non-human animals.

Our experiments provide an interesting opportunity to see whether contextual control transfers across task. This is because our participants faced two different tasks, a task with old cues and a task with new cues at test, and because both tasks included an interfering training phase in which a cue became ambiguous. According to Rosas and Callejas-Aguilera, the relationships learned during the first phase of the second task in our experiments should have become context-dependent because participants were previously exposed to interfering training trials in which a given cue became ambiguous. Thus, the expression of the learning of the A-1 and B-3 relationships trained in Context X during the first phase of the second task should have become context-dependent. This prediction can be tested because half of the participants, approximately, performed the second task in the old-cues condition in both experiments. In Experiment 1, if we only analyze participants' responses on B-3 trials, we should find a context effect when the old-cues condition is administered in the second place. In such a case, at test, participants should give faster responses in Context X than in Context Y because the B-3 relationship was first trained in Context X. However, the tendency found was just in the opposite direction: Responses tended to be faster in the XYY (*M* = 402 ms, SD = 95.77) than in the XYX condition (*M* = 470 ms, *SD* = 147.63). In Experiment 2, at test, responses should be faster on A-1 trials in the XYZ than in the XYY condition when the old-cues condition is administered in the first place. This difference should tend to disappear if the old-cues condition is administered in the second place because, in this case, the learning of the A-1 relationship should become context-dependent, leading to longer RTs when participants are presented with Cue A in Context Z instead of in the original context in which the A-1 relationship was trained. Again, our data contradicted this prediction since the difference between responses in the XYY and the XYZ conditions tended to be more pronounced when the old-cues condition was administered in second place [*M* (XYY) – *M* (XYZ) = 145 ms)] than when it was administered first [*M* (XYY) – *M* (XYZ) = 64 ms)].

Thus, taking Experiments 1 and 2 together, the evidence does not support the claim that context specificity generalizes to contexts other than that of the interfering training or to cue-outcome relationships involving non-ambiguous cues.

Of course, there are a good number of differences between Rosas and Callejas-Aguilera's (2006) and our experiments. In the former case, the learning task was framed within a causal scenario and the dependent variable used was participants' predictive judgments. Thus, a possible account of the different results is that the processes responsible for the effects found in each study might have been of a different nature. However, there are also other differences that may be responsible for the different results. For example, participants in Rosas and Callejas-Aguilera's experiments experienced several context changes within the same learning phase. This, together with the fact that contexts were labeled to induce a specific semantic interpretation, may have increased the salience of the contexts used. Further differences as the design used and the number of stimuli may also play a role to explain the different results found.

To conclude, the study reported here shows once more that the cued response reaction time task developed by González-Martín et al. (2012) can be successfully used to study interference in human predictive learning and, specifically, the mechanism by which the context modulate retrieval in interference preparations. The renewal effects found in Experiments 1 and 2 are consistent with the idea that the context of the interfering training works as an and-gate that conditions the interfering associations formed during learning rather than as an additional stimulus that form direct associations with the outcomes. The fact that the interference and renewal effects have been found by using the cued response task described here indicates that the processes responsible for these effects are based on very rapid retrieval processes based on associative activation, which is quite consistent with the associative framework for contextual control developed by Bouton and others (such as Larrauri & Schmajuk, 2008 or Nelson, 2002; 2009).

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Table 1

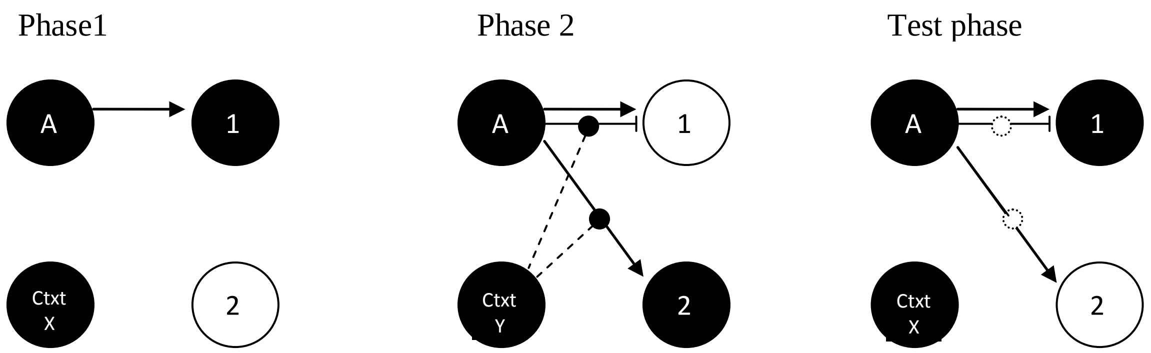
Design of Experiments 1 and 2. Groups XYX and XYZ were programmed in Experiments 1 and 2, respectively (i.e., the test context was either Context X or Context Z in Experiments 1 and 2, respectively, in these groups).

		Phase 1	Phase 2	Test
XYY	Old Cues	*Context X*	*Context Y*	*Context Y*
		A1	A2	A1
		B3	-	B3
		C4	C4	C4
	New Cues	*Context X*	*Context Y*	*Context Y*
		A1	A2	D1
		B3	-	E3
		C4	C4	C4
XYX/XYZ	Old Cues	*Context X*	*Context Y*	*Context X/Z*
		A1	A2	A1
		B3	-	B3
		C4	C4	C4
	New Cues	*Context X*	*Context Y*	*Context X/Z*
		A1	A2	D1
		B3	-	E3
		C4	C4	C4

Note. Letters stand for cues and numbers for outcomes. See text for more details.

Figure 1

Case A: Recovery as a consequence of the context working as an and-gate for the associations learned in the second phase.



Case B: Recovery as a consequence of presenting Cue A out of Context Y, which acquired an inhibitory association with Outcome 1 during the previous training phase.

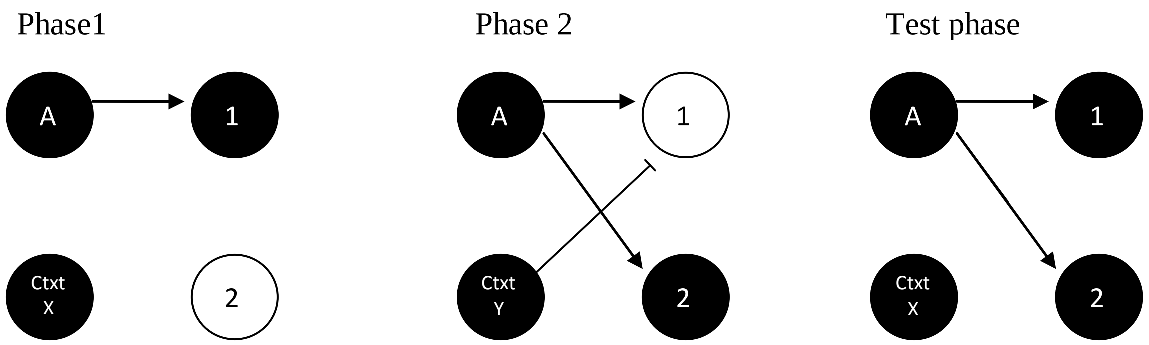


Figure 2

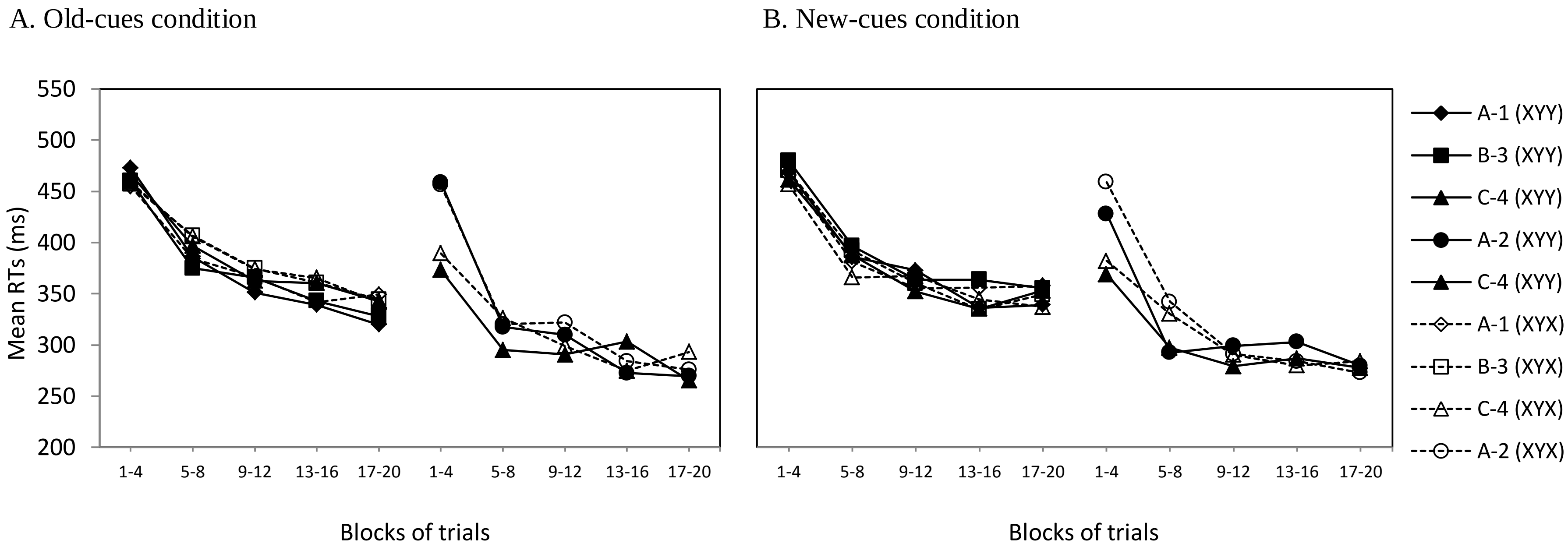


Figure 2

RTs (in milliseconds) for the different trial types during Phase 1 and 2 of the training stage from Experiment 1. Trials were collapsed in four-trial blocks. XYY and XYX refer to the no context and context change groups, respectively.

Figure 3

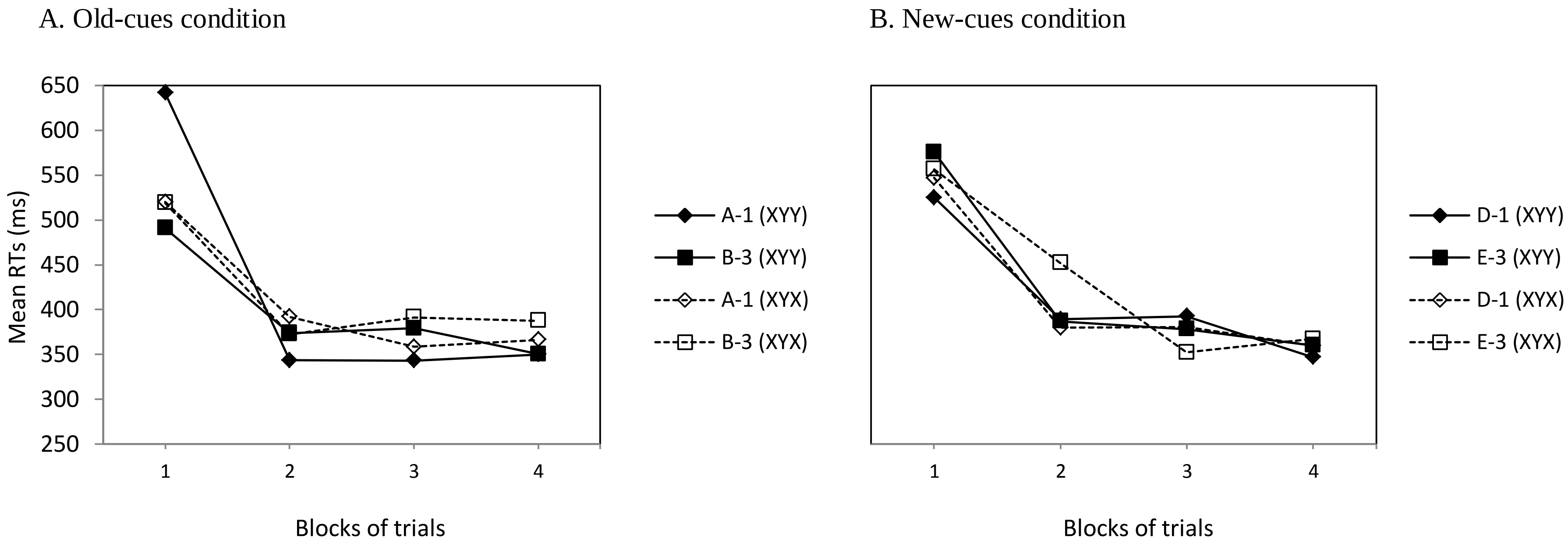


Figure 3

RTs (in milliseconds) for the different trial types across the first four trial blocks during test in Experiment 1. XYY and XYX refer to the no context and context change groups, respectively.

Figure 4

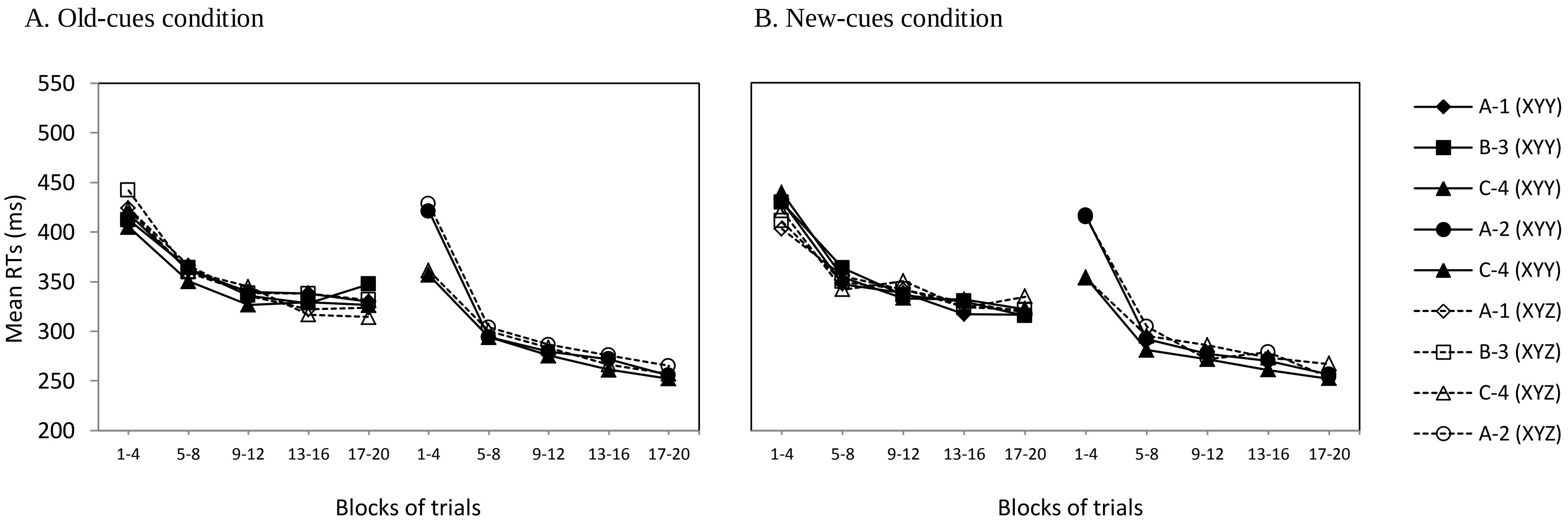


Figure 4

RTs (in milliseconds) for the different trial types during Phase 1 and 2 of the training stage in Experiment 2. Trials were collapsed in four-trial blocks. XYY and XYZ refer to the no context and context change groups, respectively.

Figure 5

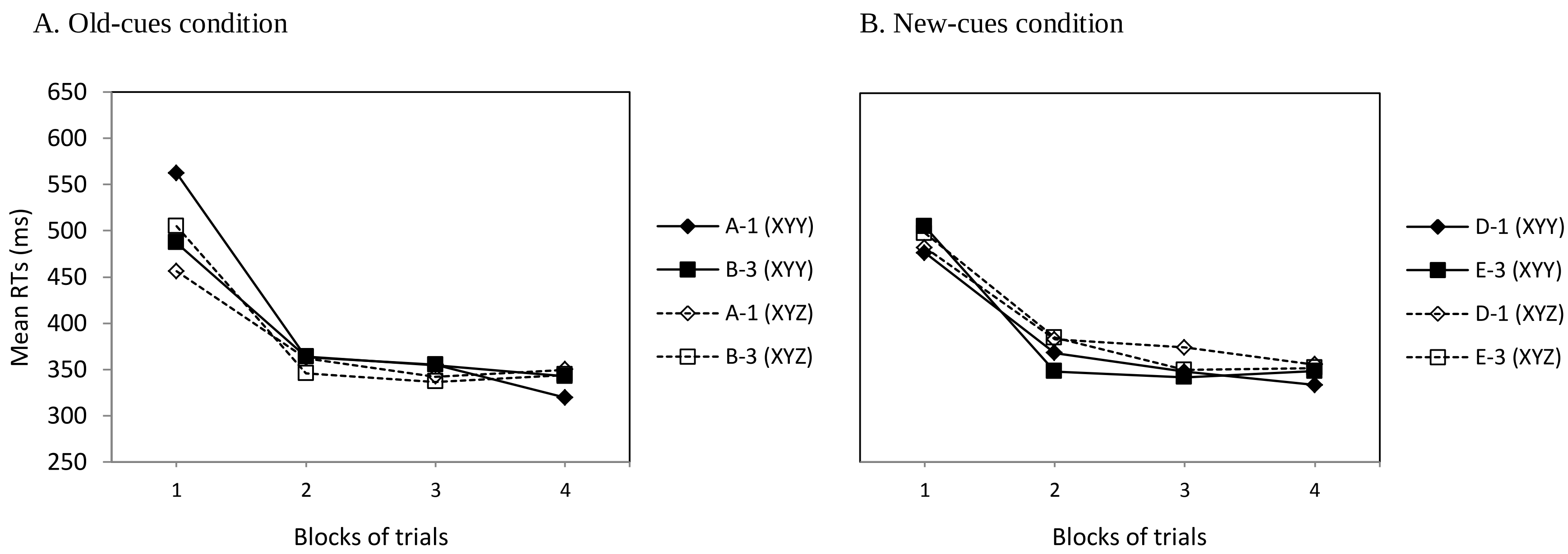


Figure 5

RTs (in milliseconds) for the different trial types across the first four trial blocks during test in Experiment 2. XYY and XYZ refer to the no context and context change groups, respectively.